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A COMPARATIVE ANALYSIS OF THE COSTS OF OPERATING MILK COLLECTION ROUTES BY CAN AND BY TANK IN CALIFORNIA

by

D. A. Clarke, Jr.

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D. A. Clarke, Jr.[1]

Foreword and Summary

Prior to the beginning of World War II, several California milk distributors utilized farm storage tanks and transport tankers, experimentally, in the collection of milk from the producers' ranches. This method has been feasible because of two factors: the development of large-scale dairy farms within the state; and the concentration of market milk production within relatively small areas located a comparatively short distance from the consuming markets.

It is not the primary intent of this report to indicate the exact level of collecting milk by tank or by cans. While it would be of unquestioned value to report such levels, it is precluded by practical considerations. Too many variables must be considered, which would modify any single figures presented, and numerous arbitrary cost allocations would be required. On the other hand, as many as possible of the cost items which enter into total cost have been carefully analyzed--both in terms of physical units of input as well as in money costs at current prices.

This approach is in conformity with the principal objective of this study, namely, to develop the variations in cost arising out of differences in input requirements, and the direction and magnitude of those factors which affect these cost differences. The individual agency may then, with knowledge of their present costs and operating conditions, determine with greater facility and accuracy the effect of a change-over to the tank method under their own particular operating conditions.

The most important of the conditions required for the tank method to result in lower cost than hauling by can, is the location of a sufficient number of large-volume producers (approximately 300 gallons per shipper) in a production area to utilize the capacities of existing types and sizes of transport tank units and farm storage tanks. The presence of this condition in many of the production areas in California has made this method particularly adaptable here.

Of the three principle components of collection costs--labor, truck, and containers--the greatest possibility for saving through the use of the tank method is

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[1] Associate in the Experiment Station and on the Giannini Foundation.

[illegible]

[illegible]

[illegible]

in terms of labor. On ranches shipping small volumes, however, the percentage of time spent at each stop making connections, agitating the milk prior to sampling, etc., is sufficiently great to outweigh the advantage of bulk handling. Urgent need exists for the development of improved procedure and equipment which would reduce the amount of fixed time required at each ranch. Until this need is satisfactorily met, continued expansion in the use of this method will be inhibited.

A greater degree of "inflexibility" exists in the available capacities of farm storage tanks as contrasted to that of cans (where available capacity may easily be increased or decreased in ten-gallon units). In addition, even though preferential discounts are available to carlot purchasers of cans, the rate of decrease in average container costs, with increased size of shipper, is more pronounced when farm storage tanks are used. For the above reasons, decreasing container costs which accompany increases in the volume per stop are of much greater consequence with the tank method. Further development of improved types and sizes of farm storage tanks is required to lessen the cost of bulk collection methods.

Bulk handling makes once-a-day milk collection possible, without the necessity for an elaborate and expensive "cold box" at each ranch. Where this is done in lieu of the common practice of a pick-up following each milking, it has the effect of doubling the "collection density," both on a per-mile and a per-gallon basis. As a consequence, truck operating expenses of the type associated with mileage, driving time, and "fixed" time (not associated with volume) are reduced.

With current techniques and at present cost rates, it becomes more economical (lower cost) to change over to the tank method of collection when the average size of shipper served is somewhat greater than 300 gallons per stop. This stipulation assumes an average route volume of approximately 3,000 gallons, and 100 miles of route travel. In arriving at the intersection of these two cost curves -- termed herein as the "break-even" point -- only the recurring costs of the can method are considered. Costs of the type that are "sunk" in the form of can-handling equipment, and from which return cannot readily be realized, have not been included.

Future changes in cost rates will affect both the level of total costs of collection under the two methods of handling, and also will affect their relationship to each other and the "break-even" point. Price increases in the factors of labor and truck operating expenses -- uniformly affecting both methods -- although increasing the level of costs, will tend to make the tank method more economical relative to the can method than at present. Increases in the costs of containers, however, when both methods are affected uniformly, will have the influence of making the tank operation relatively less favorable.

Purpose and Scope of Study

The objectives of this study are: (1) to determine those combinations of physical resources -- labor and equipment -- which will permit handling specified volumes of milk at the lowest level of money costs; and (2) in addition, to isolate and measure the net relationship between changes in money costs and changes in any one of these physical resources when all others are held fixed at some definite and specified magnitude. To achieve the first purpose, the costs associated with varying volumes will be measured for each of the two methods of handling, where the resources are so used as to reduce costs for each volume to the lowest possible level. The ultimate objective here is to measure changes in total costs for the two methods as a function of volume alone, and to compare these two cost

functions in order to determine which is the more economical under varying conditions. The second purpose is more limited. Here, the goal is to measure changes in cost when, out of specific values of factors which influence input requirements, only one of those factors is varied.

Many of the factors which enter into operating costs of the type considered in this study, are not subject to direct measurement by well-defined objective standards. Included in this category would be variations brought about by individual differences in skill of drivers, individual route conditions, and interruptions brought about by "passing the time of day," with producers. To the extent that these factors influenced cost within the sample studied, they have not been "measured out" and have been in fact "ignored." On the other hand, fairly reliable relationships between cost elements[2] and such measurable factors as volume and distance traveled can be determined for both operating methods. Cost differences based on the respective input requirements of the two methods of operation will be associated directly with factors of this latter type. The present report, therefore, is concerned primarily with: (a) quantitatively measurable factors affecting cost; and (b) factors leading to differences in can versus tank costs.

The cost elements presented herein are developed solely on the basis of those expenditures incurred in the physical transfer of a given quantity of milk from farm to receiving plant. The quantities considered are those normally handled on currently used vehicles of the type and capacity under consideration. Certain costs -- such as administrative and supervisory expenses, and differential quantity discounts on fleet purchases -- have been excluded from this analysis. Similarly, the costs of additional license fees and taxes required of contract haulers are not included. These exclusions have been made to eliminate the need for making arbitrary expense allocations and allowances within this study; this does not abrogate the necessity for the addition of appropriate amounts to arrive at total costs for individual operating conditions. Costs of this type, are associated directly with the operating characteristics of a given firm or route, are minor in amount, and will not affect the relationship between the two methods of transportation. Primary emphasis will be upon differences in costs as they are related to methods of handling. Certain other mutually incurred costs -- such as depreciation and insurance on tractors -- are quantitatively measurable and will be included in order to arrive at an approximately accurate level of total costs.

In so far as possible, the cost data developed in this report were taken directly from the operating records of firms currently engaged in hauling milk in the Bay Area, using the types of equipment specified. Cost rates have been developed and related to volume hauled and distance traveled. Three general sources of material were used: (1) in cases where variation in cost elements exists between individual trucks and concerns whose operations have been studied, and such variation can logically be expected to be distributed in a random fashion (e.g., items of variable truck expenses), simple averages of the appropriate rates were used; (2) where such variations cannot be considered as chance distribution (e.g., insurance rates paid by fleet operators, and depreciation charges based on individual company accounting policy), rates were obtained directly from a reliable source, such as an insurance company or equipment manufacturer, and applied uniformly in accordance with the basic procedure of these concerns; (3) when available cost information was incomplete (e.g., in the instance of the operating cost of vehicle

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2/ The phrase "cost elements" will appear several times within this report. When used here, it refers to the input requirements of physical resources -- labor, trucks, tanks, cans, etc. -- which require an expenditure of money in order to obtain their use.

tires, and replacement, repairs, and retinning costs of ten-gallon cans), reliable estimates were taken from operators whose experience had given them an intimate knowledge of the required rates.

The fundamental procedure in developing these cost relationships has been the synthesis, or "building up" of the various basic cost elements. Input requirements were determined in terms of physical units, and were converted to cost terms by applying appropriate costs per unit. In all cases, a full description of both physical and cost rates is presented, as well as an indication of the source of the material. The effect of changes in cost rates (prices of the factors) can be provided for since any schedule of these rates can be applied to the physical units of inputs.

Nearly all of the milk handled in fluid form in California is transported by trucks, with only a relatively small proportion carried by rail. The containers used are: (1) the standardized ten-gallon milk can in which milk is brought directly to the plant; or (2) the farm storage tank, which may be one of various capacities and holds the milk prior to the arrival of a transport tankor. The truck driver, himself normally performs the labor of loading the milk at the ranch. The driver may also unload the product at the plant, and where the tank method is employed, also measures the amount of milk received at each ranch, and takes a sample for analysis at the plant. Additional workers are required where the can method is used to receive, weigh, and to take a sample of the milk.

This analysis of milk assembly and transportation will be developed on the basis of: (1) truck operating cost; (2) labor cost; and (3) container cost. Each of the components of cost within these classifications will be treated separately and later summarized in terms of total cost.[3/] Once developed in this form it will then be possible to further classify these total costs in terms of those directly associated with: (1) the number of shippers to be served in a particular area or on a particular route; (2) the volume of milk to be handled; and (3) the number of miles to be traveled to serve that area or route.

As total costs of the nature described in this report are directly associated with operating conditions, these costs will be developed for hypothetical cases, using rigidly defined specifications regarding such factors as the distance to be traveled, volume handled, and number and size of shipper. The direction and magnitude of the effect of these factors will be further studied by varying the values of one factor (such as the size of shipper) while holding all others constant at their previously defined values.

It should be emphasized, however, that relative operating costs are not the sole factors to be considered. Of equal or perhaps greater consequence are: (1) the effect of tank transportation on the quality of the product, both from a bacteriological and a physical standpoint; and (2) the location of farms in relation to roads adequate to support the heavy equipment required.

While these factors are beyond the scope of this report, that of the effect upon quality has received considerable attention elsewhere. In reference to the maintenance of quality, the tank method is reported superior to hauling in cans. According to Dr. C. L. Roadhouse, of the Dairy Industry Department, College of Agriculture, University of California, "the temperature of the milk in insulated

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3/ With the exception of the previously mentioned costs which have been excluded, such as administrative and supervisory expenses.

truck tanks can be maintained at a lower point, (and) dust contamination is eliminated ..." In a study made in cooperation with the Oakland City Health Department, Dr. Roadhouse reports shipments from a country plant, part of which was transported by tank, and a portion of which was pumped into cans and carried in an enclosed trailer along with the tank. The distance traveled between plants was 90 miles. Records were taken of the temperature and bacteria count of the milk as it reached its destination, for a total of twenty shipments.

The following averages were found:[4/]

	Tank shipments	Can shipments
Temperature of milk	44.4°F	48.3°F
Average bacteria count	32,273	68,568

From a physical standpoint, the question has been raised regarding the possible effect of "churning action" on milk transported over distances in partially filled tanks. To determine these effects Dr. Roadhouse conducted a study of the influence of agitation of milk at different temperatures. In this experiment, several samples of milk were agitated and photomicrographs were taken of the fat globules, noting coalescences and butter formation. The results of this experiment indicated that, "raw milk cooled at the farm and later transported to the city plant will not coalesce or show physical changes if the temperature is held at 40°F or below. Likewise, no physical change will occur if the temperature is held at 45°F or below ... At 50°F the fat globules will coalesce and form small masses of fat if the milk is allowed to agitate in partially filled tank truck or cans ... At 60°F the fat globules will coalesce further upon agitation and form larger fat masses and collect on the surface as butter ..."[5/] The conclusion reached by Dr. Roadhouse was that milk should be transported in full containers unless the temperature is maintained at 45°F or below; otherwise, physical changes of the fat will occur that will be detrimental to the product.

No information is presented regarding the number of farms which, because of their location on poor roads, could not be adequately served by tank trucks. There is no question, however, that complete utilization of the tank truck method will be restricted to the extent that the required heavy equipment can gain access to certain farms. It is still too early in the development of this method to prognosticate upon the effect of this particular technological change in transportation upon the future location of market milk production.

Truck Operating Costs

Cost factors concerned in the operation of motor vehicles can be segregated into two classifications: those which are "fixed" over a period of time, and those which are "variable" with day-to-day operations. In the first category would logically fall such expense items as depreciation, insurance, interest, taxes and licenses, general garage, and overhead administration. Fuel, lubricants, repairs, and tires are "variable" in that exponses incurred for these items are dependent upon the mileage traveled, etc.

[4/] As reported by Dr. Roadhouse in an address before the Dairy Industries Conference, February 10, 1947, held at Davis, California.

[5/] Ibid.

Records relative to the cost of operating 119 milk collection trucks for an aggregate of nearly 6⅔ million truck miles, were collected from distributors and contract haulers. In most cases, these records gave the original investment in equipment, taxes and license fees, insurance premiums, overhead garage and administration expense, fuel and lubricants used, repairs, and tire expense. The majority of records also indicated the mileage traveled and the amount of milk hauled.

These records have been analyzed and the results are presented in the following sections. The writer has made reference, also, to physical input data presented in a report published by the California Railroad Commission.[6/] This report covers the cost of transporting all types of property by truck in more comprehensive detail than the scope of the present report allows.

In presenting these operating cost relationships, it is recognized that the results will not be applicable to any particular truck, owing to the fact that considerable variations in performance exist, even between trucks of identical make, age, size, and mileage traveled. Operating costs are influenced by many non-quantitative factors, such as the driver's skill, which are impossible to measure in a report of this nature. It is felt that to a large extent, however, errors caused by such variations are compensating in that they tend to counteract the effect of each other. In the final analysis, these variations will "balance out," and reliable average relationships can be measured.

Transport tankers, and the van-type can-hauling trailers, are normally powered by the same type of tractor. Because of the topography of the milkshed for the San Francisco-East Bay Market, a heavy-duty tractor is commonly used. These tractors may haul one or two tank or van trailers, or may carry a combination of a can trailer and a tank. In view of the similarity of the type, size, and gross weight of the vehicles, and of the condition of roads traveled and traffic encountered, cost factors relevant to both the can (large van) trailers and transport tanks will be considered together. The smaller, open-rack can truck, will be considered separately, since it is normally supplied with a much smaller power unit, and carried less gross weight.

The smaller trucks were both of the type with the body directly attached to the chassis, and the single semi-trailer unit. In all cases, the cans of milk were carried on flat-bottomed rack bodies. These trucks were not enclosed, except for a canvas tarpaulin across the top. They normally carry a load of between 100 and 150 cans, and are powered by a low priced tractor or truck with a manufacturer's rated capacity of 1½ to 3 tons.

This report will deal primarily with the three types of vehicle units mentioned above: (1) the tank unit, which may be either the large single unit with capacity up to 3,800 gallons, or the two unit tank train with a total capacity approximating 4,500 gallons; both of these units are powered by a heavy-duty tractor; (2) the enclosed insulated van-type can unit, which may be a semi-trailer or two unit "train" with a capacity of 400 cans, also powered by a heavy-duty tractor; and, (3) the light-duty truck or semi-trailer, with a capacity of approximately 135 cans. The types of costs to be studied are: fuel and lubricant (applying only to tractors); repairs; tires; general garage (including storage); depreciation; insurance; taxes and license fees; and interest on investment in vehicular equipment.

6/ Chestnut, Fred H. Study of Transporting Property in Motor Trucks Between Points in California. Engineering Division, Transportation Department, California Railroad Commission. September, 1937.

Fuel and Lubricants

Heavy-duty tractors currently engaged in the operation of collecting milk in the San Francisco-East Bay milkshed use either gasoline, butane, or Diesel oil, while the smaller units all utilize gasoline as fuel. The average consumption of these fuels, together with the appropriate average cost per gallon and per mile, as determined in this study, is as follows:

Table 1

Summary of Fuel Operating Costs (tractors only)

Type of tractor	Type of fuel	Miles per gallon	Cost per gallon	Cost per mile
			Dollars	Dollars
Heavy duty:				
	Butane	3.0	0.130	0.0433
	Gasoline	3.5	0.168	0.0480
	Diesel	5.0	0.090	0.0190
Light duty:				
	Gasoline	7.6	0.168	0.0221

The weighted average fuel cost per mile amounted to $0.0455 for the heavy-duty units. As all of the light-duty units were powered by gasoline operated engines, the cost per mile for these units is $0.0221.

The amount of oil consumed is normally considered to be an index of the state of repair of the motor. Wide variation in physical inputs of oil and grease and other lubricants was found to exist. In general, however, consumption of oil and other lubricants, in cost terms, was found to approximate 10 per cent of the expense for fuel. This relationship is further borne out in the cost figures presented by Chestnut.[7]

Oil and other lubricant cost for heavy-duty tractors average approximately $0.0045 per mile. For the lighter weight trucks an amount of $0.0023 was found applicable for these costs.

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[7] Ibid. In 1937, this study reports a weighted average fuel cost, for trucks of this type, of $0.0294 per mile, and a cost of lubricants of $0.0029. This rate of consumption, however, considers travel over valley highways and at a 1937 price level.

Repairs[8]

Expenses included under repairs are the cost of the parts and materials, plus the amount paid for labor to service, maintain, and repair trucks and tractors of these types. Due to the shortage of new equipment, the increased burden placed on transportation facilities, and high prices for labor and material, expenses of this type have become increasingly important in operating costs. Because of the effect of these war-born conditions, current repair expenses reported by truck operators are substantially higher than reported by Chestnut,[9] and also in other studies made during more "normal" times. For the heavy-duty type tractors, a mean level of repair cost of $0.0850[10] per mile was determined from the records studied. The previously mentioned study pointed to a repair expense in 1937, for trucks of similar size operating primarily over valley highways, of $0.0332 per mile. Data which were available for this study indicate that the cost of materials used in repairs and the physical inputs of man-hours of mechanics' labor spent making repairs show a rapidly increasing cost per mile until approximately a year after the war's end, when a few new truck units became available. With the addition of these new units, which obviously had a significant effect upon the composition of the two samples -- before and after the addition of new units -- the average per-mile repair costs showed a significant decrease. As was true in the case of the larger trucks, repair expenses for the

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[8] Repairs can normally be thought of as increasing with age and use at an increasing rate, until it becomes necessary to replace or rebuild the motor. After this large expenditure has been made -- which is also considered a repair cost -- average repair costs gradually decline for a period, and then begin to rise at an increasing rate until it is again necessary to make a major overhaul. In this manner, average repair costs covering the full life of an individual truck may be expected to follow a wave-like pattern with high peaks occurring at the times of the high expenditure. In addition to these wave-like variations, the general level of repair costs will also rise, so that each peak will tend to be higher than the preceding one. Because of this fact, it is important that the age and/or mileage distribution of a sample to be used to approximate average repair costs for all other similar vehicles, correspond with the age and mileage distribution of all other vehicles to which this rate is to be applied.

The data which were used represented total repair costs over a period of time (usually a month) for the entire fleet. Total mileage traveled by the fleet during the period was also available, but no information could be obtained regarding the composition of the fleet in terms of the age and mileage distribution of the individual trucks of the fleet, nor could the allocation of repair costs between the individual trucks be made. It is very likely, since the sample used covered a period of operation during which vehicular equipment was in critically short supply, that both the age and mileage distribution of this sample are abnormally high.

[9] Chestnut, op. cit.

[10] In spite of the limitations pointed out in footnote 8 above, this figure will later be applied, in lieu of a more reliable estimate, to obtain total costs of truck operation, and further for costs of the entire operation. The error caused by the probable existence of a sample with an abnormally high mileage distribution, while important from the standpoint of total repair costs, will be of minor consequence in terms of total collection costs (including other truck costs, labor costs, and container costs).

smallor trucks were relatively high during the immediate postwar period. For the trucks studiod, average repair expenses amounted to $0.0754.

Tires

In order to arrive at accurate cost information on tire expense, it is necessary to have data covering the total life of the tire, including the original investment, the number of miles run on each position on the vehicle, the amount spent for repairs, recapping, and the salvage value, if any. As those records were not currently available, it is necessary to rely on estimates based upon the experienced judgment of the operators of these trucks. According to these estimates tires used on driving wheels are good for 25,000 miles, while trailer tires and steering tires will give a life of 60,000 miles. This is an estimate of life prior to recapping, and considers the size of loads handled and the condition of roads traveled. It is also estimated that these tires can be recapped, on the average, just once, and that this, again on the average, will increase the mileage by 50 per cent. On this basis, cost per mile per tire can be determined and applied to each unit according to the number of tires on driving and on steering and trailer positions.

Table 2

Tire Cost Per Mile: Heavy-Duty Trucks

	Original cost plus one recap [a]	Miles of service	Cost per mile per tire
	1	2	3
	Dollars		Dollars
Driving wheels	124.39	37,500	0.0033
Steering and trailer wheels	124.39	90,000	0.0014

[a] Based on original cost of 11:00 x 20 tires of $104.09 and $20.30 for recap.

Total tire cost per mile for various combinations of units is as follows:

Table 3

Unit Tire Cost Per Mile: Heavy-Duty Truck Units

	Number of drive wheels	Number of steering and trailer wheels	Tire cost per mile [a]
	1	2	3
			Dollars
Tractor and semi-trailer [b]	4	6	0.0216
Tractor and semi-trailer [c]	4	10	0.0272
Tractor, semi-and trailer	4	14	0.0328

a/ Obtained by multiplying cost per mile per tire (col. 3, table 2) by number of wheels in each position (col. 1 or col. 2, table 3) and adding the products.

b/ Single axle semi-trailer.

c/ Double axle semi-trailer.

For the smaller sized trucks, tire cost per mile based on a large number of truck records, amounted to an average of $0.0153.

General Garage

In maintaining motor vehicles there are certain expenses, in addition to repairs, such as washing and painting, and providing storage space when the equipment is not in use. The magnitude of these expenses varies according to the amount of service performed and the type of storage facilities provided. In attempting to determine these costs for the truck records studied, some difficulty was encountered in that it was necessary to pro-rate the total expenses of this nature over an entire fleet, composed of many different sizes and types of trucks with wide variations in space requirements and in the frequency with which these services were performed. The resulting average cost for the light-duty trucks and tractor and semi-trailer units, amounted to slightly less than $300 per year. Those for the larger heavy-duty units (tractors and trailers) was approximately $420.11/

Depreciation

In common accounting procedure, depreciation is designed to set aside a reserve to provide for replacement of equipment when it is worn out or obsolete, or for repaying the original investment in that equipment. A wide range in depreciation charges was found in the records of trucks studied. In some instances the policy of the company was to spread the investment over the total expected life of the vehicles concerned, while others preferred to use the maximum rates allowable by the United States Internal Revenue Department.

The most useful procedure for determing actual depreciation costs is to allocate the difference between original cost and salvage value, over the entire period of useful life of the truck. Even when this procedure has been accepted and adopted, however, certain arbitrary decisions must be made which have important effects upon the resulting cost figures. There is a wide variation in quality and consequently in the investment in equipment that is designed for, or applied to, the same use. In practice, part of this difference is normally offset by differences in length of useful life and in repair costs.

11/ These figures (as well as other types of cost of similar nature) will be used later to determine total "fixed" operating cost. This total "fixed" cost can be put on an average cost per mile basis by dividing by average annual mileage.

Chestnut[12] has set up a table showing estimated years of useful life which varies inversely with annual mileage. This is, in effect, a straight-line ratio between trucks traveling a maximum of 5,000 miles a year, to which he allots a ten-year life span, and those covering up to 100,000 miles a year over a five-year use period. By using this table, and applying to it the average yearly mileage of the trucks studied -- which amounted to approximately 47,000 miles per vehicle -- a total useful life of 7.5 years can be determined. For the lighter weight trucks, most of which are operating at a closer to overload capacity, the length of useful life is normally less than for the heavy-duty tractor. Depreciation charged on the basis of a five-year life will be used to approximate actual costs for these trucks. This is the rate commonly used by firms employing this type of vehicle who follow the policy of "spreading" depreciation over the expected period of useful life of the equipment.

Consensus of opinion, however, indicates that the life of a trailer is normally greater than that of the tractor that pulls it, since repair costs do not mount as rapidly in relation to depreciation costs as they do on the power equipment which involves a greater degree of mechanical wear and tear. A depreciation rate of 10 per cent for trailer equipment appears reasonable.

Presented below in table 4 are average investment figures, depreciation rates, and annual depreciation charges for equipment now in use in the San Francisco-East Bay milkshed, when the aforesaid life expectancies for each type of equipment are applied to determine depreciation rates.

Table 4

Investment, Depreciation Rate, and Annual Depreciation Charges for Milk-Hauling Equipment

Item	Average investment[a]	Rate of depreciation	Annual depreciation charges
	1	2	3
	Dollars	Per cent	Dollars
Tractor (heavy duty)	5,760	13.3	766
Van semi[b]	3,990	10.0	399
Van trailer[c]	2,120	10.0	212
Tank[d]	6,900	10.0	690
Tank[e]	5,800	10.0	580
Converter gear	1,480	10.0	148
Tractor (light duty)	2,000	20.0	400
Semi-trailer (rack)	1,000	10.0	100
Truck	2,500	20.0	500

[12] Op. cit.

a/ Average costs as determined by records studied have been "rounded off."

b/ 250-can capacity, 21-foot body.

c/ 150-can capacity.

d/ 3,500-3,800-gallon transport tank. Two axle semi. Usually drawn as a single unit.

e/ 2,000-2,500-gallon transport tank. One axle semi or full trailer with use of converter gear. Hauled either separately or in double unit.

Source: Col. 3: Col. 1 x col. 2.

Insurance

Insurance premiums are subject to a variety of discounts and surcharges. Fleet reductions, adjustments on the manual rate according to exposure and experience records of the particular concern being insured, and the class of owner, whether contract hauler, cooperative or distributor owned, all have important effects on the actual amount of the premium paid. In addition, there are rate variations dependent upon the locality in which the vehicle is garaged and the radius of the area covered from that base. Some insurance companies also provide for a discount or a rebate in the form of a dividend, depending upon their claims experience during the previous insurance period.

Presented in table 5 are the basic manual rates covering items of equipment of the type included in this study. Class 3 rates pertain to local truckmen, or contract haulers, while Class 4 would be applicable to distributors or producer cooperatives who own the milk being transported.

Insurance rates against fire and theft are normally set on the basis of the age and value of the equipment. Trucks under 18 months old are covered for fire insurance at the rate of $1.00 per year for each $100 of value, while those over 18 months old are charged at a rate of $1.50 per $100 of value. Theft insurance for equipment of this type amounts to $0.25 per $100 of value. As the concerns whose truck records were studied maintained and performed their own repair and service shops, costs of the type normally covered by collision insurance are included under the heading of repairs.

Assuming a discount rate of 30 per cent on the manual rates, the heavy duty collection truck, with semi-trailer plus trailer, operated by a distributor or cooperative producers association, could be covered by property damage and public liability insurance by an annual premium of $235.00. The premium for the smaller unit, assuming a semi-trailer, would approximate $162.00.

Table 5

Basic Manual Insurance Rates, Truck Units Garaged in Bay Area, Traveling in a Radius of Not More Than 50 Miles From Base[a/]

Type coverage	Class 3	Class 4
	Dollars	
Tractor:		
Bodily Injury $100,000/300,000 limits	191.80	128.78
Property Damage $5,000 limit	123.00	81.00
Semi-trailer:		
Bodily Injury $100,000/300,000 limits	19.18	12.88
Property Damage $5,000 limit	12.30	8.10
Trailer:		
Bodily Injury $100,000/300,000 limits	95.90	64.39
Property Damage $5,000 limit	61.50	40.50

a/ Courtesy of Liberty Mutual Insurance Company.

State Taxes and License Fees

Three types of fees are collected annually on trucks by the California Department of Motor Vehicles. They are the registration fee, the weight fee, and the personal property tax. The registration fee amounts to $3.00 per year per vehicle, regardless of size or type. Weight fees are based on highway usage, and vary in accordance with the light weight, or tare, of each registered vehicle, and the number of axles. Presented below is a schedule of fees of this type for the various weights and axles shown.

Table 6

Basic Data Concerning Water Conservation Districts in the State, December 31, 19--

Item	District A	District B
Organized:		
Petition Filed:		
Date, Month/Day/Year	12/15	10/28
Election Ordered:		
Date, Month/Day/Year	12/20	11/2
Election Held:		
Date, Month/Day/Year	12/31	12/7
Results Known:		
Date, Month/Day/Year	12/31	12/7
Vote:		
For	47	62
Against	13	38
Directors Appointed:		
Date, Month/Day/Year	1/10	12/17
Directors Qualified:		
Date, Month/Day/Year	1/10	12/17
Organization Completed:		
Date, Month/Day/Year	1/10	12/17

1/ Secretary of State Water Conservation Commission.

Table Given for Illustrative Purposes

Basic Data Concerning Water Conservation Districts in the State, December 31, 19--

Item	District A	District B
Organized:		
Petition Filed:		
Date, Month/Day/Year	12/15	10/28
Election Ordered:		
Date, Month/Day/Year	12/20	11/2
Election Held:		
Date, Month/Day/Year	12/31	12/7
Results Known:		
Date, Month/Day/Year	12/31	12/7
Vote:		
For	47	62
Against	13	38
Directors Appointed:		
Date, Month/Day/Year	1/10	12/17
Directors Qualified:		
Date, Month/Day/Year	1/10	12/17
Organization Completed:		
Date, Month/Day/Year	1/10	12/17

1/ Secretary of State Water Conservation Commission.

Table 6

Schedule of Weight Fees, as Issued by the State of California, Department of Motor Vehicles, Division of Registration on December 10, 1937

Vehicle classification	Annual weight fee
	Dollars
Two-axle trucks, trailers, and semi-trailers:	
3,000 to 5,999 pounds tare	8
6,000 to 9,999 pounds tare	40
10,000 or more	50
Three-axle trucks and trailers:	
3,000 to 5,999 pounds tare	8
6,000 or more	70

The personal property tax varies according to the value of the equipment, and is levied at the rate of $1.75 per $100 of assessed valuation.

Table 7

Taxes and Liconse Fees for Milk Collection Trucks -- State of California

Type of truck	New value[a]	Property tax[b]	Registration	Weight fee
	Dollars			
Truck or light-duty tractor and semi-trailer:				
Truck	2,500	21.87	3	8
Tractor	2,000	17.50	3	8
Semi-trailer	1,000	8.75	3	8
Heavy-duty tractor with insulated vans or tanks:				
Tractor	6,000	52.50	3	40
Van -- 250 cans	4,000	35.00	3	40
Van -- 150 cans	2,000	17.50	3	40
Tank -- 3,500-3,800 gallons	7,000	61.25	3	40
Tank -- 2,000-2,500 gallons	6,000	52.50	3	40
Converter gear	1,500	13.38	3	--

[a] Approximate.

[b] Based on assessed valuation of 50 per cent new cost over useful life of equipment.

Interest

Although not usually included in the cost records kept by most concerns operating trucks of this type, except on the basis of payment made for borrowed capital, interest payments on the unamortized portion of the investment in this equipment must be included in this type of an analysis. Most business concerns are limited in the amount of capital available for such investments, therefore, it must be expended so that it will obtain at least the rate of interest it would earn in its best alternative use. Annual costs for interest depend upon the amount of the original investment, the years of useful life over which the investment is "spread," and the interest rate.

They can be expressed in formula form by the following equation:

$$I = \frac{A}{2}(r)\frac{(n+1)}{n},$$

where I is the annual cost, A the amount to be amortized (original investment less salvage value at the end of the useful life), r the interest rate, and n the number of years of useful life. Applying this formula, and a rate of five per cent,[13] interest costs for the types of trucks under consideration have been approximated and are presented in summary form in table 8. Annual costs for the straight truck amount to approximately $75, while those for the light-duty tractor and semi-trailer amount to $87.50. For the heavy-duty classifications, depending upon the make-up of the unit, annual interest costs range from $280 for a tractor and one 250-can van, to over $540 for a train composed of tractor, two 2,250-gallon tank semi-trailers, and a converter gear.

Table 8

Interest Costs for Milk Collection Trucks

Type of unit	Amount to be amortized	Years of useful life	Annual interest cost
	Dollars (A)	(n)	Dollars (I)
Truck (light-duty)	2,500	5	75.00
Tractor (light-duty)	2,000	5	60.00
Semi-trailer (open rack)	1,000	10	27.50
Tractor (heavy-duty)	6,000	7.5	170.00
Van (250-can capacity)	4,000	10	110.00
Van (150-can capacity)	2,000	10	55.00
Tank (3,500-gallon)	7,000	10	192.50
Tank (2,250-gallon)	6,000	10	165.00
Converter gear	1,500	10	41.25

[13] Arbitrarily selected as the rate of return for alternative investment.

Summary of Operating Costs of Milk-Collection Trucks

All of the expense items previously discussed are brought together in table 9. For the purpose of indicating the total of these costs on a unit basis, certain types of equipment have been combined as being typical of units now in operation in the San Francisco-East Bay area. Unit "A", therefore, would be representative of the light-duty truck or semi-trailer, used to haul milk in cans to a country receiving station or, in some cases, direct to the processing plant. Unit "B" is typical of the insulated van-train consisting of a semi-trailer and a four-wheel trailer that are employed by the large contract haulers and distributors in bringing milk directly to the processing plant from the farm in cans. Unit "C" consists of the large semi-trailer transport tank with a capacity of 3,500 to 3,800 gallons while Unit "D" is made up of two somewhat smaller semi-trailer tanks, the combined capacity of the two tanks amounting to 4,500 gallons. Both of these latter type tank units are currently operated in making bulk milk pickup at the producer's ranch in the Bay area milkshed.

As would be expected, due to the similarity of the tractors used in the heavy-duty units, their average costs of the type which vary with mileage are nearly identical. The small variation for Unit "C", is caused by the fact that tire expense is less on those units, since fewer tires are required on a semi-trailer than on the train units.

Expenses unrelated to mileage have been determined according to the rates set forth in the discussion of those items, applied to the average valuations and weights of the units as determined in the study. In order not to infer a degree of accuracy greater than actually possessed, these figures have been "rounded off" in determining operating costs under particular operating conditions.

Table 9

Summary of Truck Operating Costs

Type of cost	Unit A[a]	Unit B[b]	Unit C[c]	Unit D[d]
	Cost per mile			
	Dollars			
Fuel and lubricants	0.0221	0.0500	0.0500	0.0500
Repairs	0.0754	0.0850	0.0850	0.0850
Tires	0.0153	0.0328	0.0272	0.0328
Subtotal	0.1128	0.1678	0.1622	0.1678
		Cost per year		
General garage	300	420	420	420
Depreciation	500	1,378	1,456	2,075
Insurance[e]	181	309	320	404
Taxes and licenses[f]	48	234	200	303
Interest	88	335	362	541
Subtotal	1,117	2,733	2,755	3,743

a/ Light-duty truck or tractor with flat-bodied semi-trailer. Average load 135 cans.

b/ Heavy-duty tractor with 250-can insulated van semi-trailer plus 150-can trailer. Average load 350 cans.

c/ Heavy-duty tractor with 3,500 gallon transport tank semi-trailer.

d/ Heavy-duty tractor with two 2,250 gallon transport tank semi-trailers plus converter gear.

e/ Fire and theft premiums based on insurable value of 50 per cent of new cost over useful life of equipment.

f/ Property tax based on average assessed value of 50 per cent of new cost over useful life of equipment.

Table 10 presents on a comparative basis the cost per gallon of transporting milk (in various quantities) by different units. Cost per gallon expenses are shown for each type of equipment, load size as indicated. Costs related to mileage have been computed on a daily basis for routes of varying lengths and added to daily cost of the type not directly related to mileage.

Table 10

Operating Costs Per Gallon of Milk Collected, Varying Length of Route

Daily mileage	Unit A (1,350 gallons)	Unit B (3,500 gallons)	Unit C (3,500 gallons)	Unit D (4,500 gallons)
	Dollars			
50	0.0064	0.0045	0.0045	0.0041
100	0.0106	0.0069	0.0068	0.0060
150	0.0148	0.0093	0.0091	0.0079
200	0.0190	0.0117	0.0114	0.0097

LABOR REQUIREMENTS ON MILK-COLLECTION ROUTES

Information regarding labor requirements for milk-collection routes was obtained by riding several assembly trucks. Stop-watch observations were made of the component operations necessary to bring the milk from the producers' ranches

to the city processing plant. These observations were focused on the relative labor-inputs required by two methods now in use in the San Francisco-East Bay milk-shed: the transport tank method, in which the milk is pumped directly from the farm-storage tank, and the can hauling method, where 10-gallon cans of milk are loaded into a flat-bedded truck. These time studies encompassed the loading operation at the ranch, transporting the milk over the highways to the city processing plant, and the unloading of the product at the plant. This study includes only that time required to perform the "productive" operations directly concerned with the collection of milk. Time for the driver's lunch, the delivering of products and supplies to the shipper, time spent talking to producers, and the driver's personal time are not included in the following discussion, nor has consideration been given to time spent on ferries, at weighing stations, etc. In making up an actual route and determining "standard time" requirements, it is quite logical that an over-all factor should be added to include these expenditures of time for that particular route.

FACTORS AFFECTING TIME REQUIREMENTS ON TANK ROUTES

Loading

Time requirements for loading milk in bulk from a farm-storage tank may properly be considered in two categories: that amount of time which is fixed per stop (unrelated to the volume of milk handled), and that time which varies with volume.[14/]

These operations which must be performed, but which are not associated with the physical volume of product handled include: (1) measuring the amount of milk contained in the farm-storage tank; (2) agitating the milk over a period of time sufficient to thoroughly redistribute the cream so that a fair sample can be taken for butterfat and bacteriological analysis at the plant laboratory; (3) taking a sample of the milk, and recording the temperature and the volume of milk received; (4) making the necessary pipe-line connections from the storage tank to the transport tank; and (5) disconnecting this pipe, rinsing the tank, and performing all the other post-pumping operations which must be completed prior to leaving the ranch.

That amount of time which is directly associated with volume handled is the length of time that the pump is in operation.

In addition to the time requirement mentioned, a certain amount of "other" time was normally spent at each ranch. This usually consisted of the driver's personal time, and that spent "passing the time of day" with the producer; the latter might conceivably be charged against building up the company's "good will." Time spent in this manner was minor in amount.

Fixed Time for Loading Operations

A great deal of variation in time requirements was noted in the operations classified above as "fixed." In the first place, the largest single time-

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14/ In so far as possible throughout this report, the terms "fixed" and "variable" will be used to denote the relationship of time expenditure and cost, to volume of product handled.

consuming factor was that of agitating the milk so that a proper sample could be taken. Although some of the smaller tanks required manual agitation, the majority of the tanks observed were equipped with an electrically operated mechanical agitator which varied in size and power with the size of the tank.

As it is left to the judgment of the driver to determine when the milk has become thoroughly mixed, and as this is a highly subjective decision which depends largely on the individual, it is only to be expected that relatively large variations will occur. The range in time spent agitating was from 2.5 minutes to 15.5 minutes, with an average time for all observations of 7.1 minutes. In one instance, the mechanical agitator was turned on prior to the arrival of the pick-up truck at the ranch, so that no actual time was required of the driver for this operation. But this is not the usual case, since it is believed that the measurement of the milk is more accurate, when a dip-stick is used, if done prior to agitation.

Another operation in which differences in "fixed" time requirements occurred was that of connecting and disconnecting the pipe from the storage tank to the transport tank. In some instances it was observed that it was necessary for the driver to "build up" all of the pipe and then dismantle it again after the pumping was completed. In these cases the driver also flushed out the tank and pipe with clear water, thus making the job of cleaning easier for the "clean-up" man at the farm. In other cases, the pipe had been set up at the farm prior to the arrival of the tanker, and the driver had merely to make one connection, using a flexible rubber hose which was attached to the intake of his tank. The amount of time spent making connections, however, was not important as far as total time expended was concerned, since this was normally done during the time the mechanical agitation was taking place. Disconnecting the pipe line, however, was of more importance since it added to the total time for the stop. The observed range in time spent disconnecting was from 45 seconds to 3-1/3 minutes, with an average time expenditure of 1.5 minutes.

In determining the amount of time that will be required to perform these operations which are unrelated to volume, for any particular shipper the effect of the above factors must be considered. (For purpose of this description, however, an average of the total observed "fixed" time.) This average amounts to 10.1 minutes and covers the range of from 5.7 minutes to 19.2 minutes.

Variable (Loading) Time

As far as could be determined, all of the pumps used to transfer milk from the storage tank to the truck tank were of the same capacity. Variations in loading time per gallon, however, were observed and are believed to be the result of one, or a combination, of the following factors: (1) variations in electrical power supply to the pump motors and variations in the efficiency of the motor; (2) variations in the pumping efficiency of the pump itself; and (3) variations in the construction of the tanks, which affected the efficiency of drainage.

Of those factors, it is felt that the latter is the most important. The rate of operation of these pumps is 60 gallons per minute. For the purpose of this description, the total time required for pumping associated with various volumes can be described by this rate of pumping of 60 gallons per minute, or 0.0167 minutes per gallon.

Total Time for Loading

The total time required for loading milk into tank trucks from farm-storage tanks can be expressed by adding the average variable time requirements to the average of the fixed time observations. This can be expressed by the formula:

$$LT_t = 10.1N + 0.0167\ G,$$

where LT_t equals the total loading time in minutes, N the number of shippers, and G the amount of milk, in gallons, to be loaded.

Unloading Operations -- Tank Trucks

As in loading, the time requirements for unloading a tank truck at the plant can be broken down into "fixed" and "variable" time. Operations necessary prior to unloading the milk, such as making pipe connections, agitating the milk to redistribute the cream, taking a sample for further laboratory analysis, and disconnecting the pipe lines after the product has been unloaded, constitute factors which are "fixed" in relation to the volume handled. Another operation, while not directly a part of the unloading operation, but the inclusion of which is necessary at this point in order to maintain comparability between the two types of operation, is that of washing and sterilizing the empty tank.

Differences in time expenditures exist here to a substantial degree. These variations, however, are more likely to be associated with differences in operating conditions at the plant, such as the location of the area at which the tank is to be unloaded, the amount of pipe line that must be constructed in order to make the connections to the storage tank, and, most important, by the thoroughness and the conscientiousness of the "clean-up man" in washing and sterilizing the tank.

The average time expenditure for these operations, connecting and disconnecting the pipe line, agitating, sampling (including taking a temperature reading), and washing and sterilizing the tank amounted to 25.3 minutes.

The pumps used at the plant for unloading were similar in capacity to the 60 gallon per minute pumps used in loading the milk at the ranch. Using this observed rate and applying it to the arithmetic mean of time expenditures on operations not associated with volume, we can approximate the time requirements for unloading tank trucks by the formula:

$$UT_t = 25.3 + 0.0167\ G,$$

where UT_t represents unloading time in minutes, and G the number of gallons to be unloaded.

Driving Time[15]

Related to the single factor of distance, driving time can be expressed as:

$$DT = 2.727\ M,$$

where DT represents total driving time in minutes, and M the number of miles to be covered.

Total Time for "Productive" Operations on Milk Collection Routes Using Tank Trucks

In summary, the total time requirements for "productive" operations, based on the above relationships and incorporating the use of certain averages found to exist in the observed cases, can be estimated by the addition of the time expenditure of the component parts. The effect of combining these separate operations is shown in table 11.

Table 11

Summary of Total Time-Requirements for Collecting Milk by Tank Truck[a]

Operations	Minutes per route	Minutes per stop	Minutes per gallon	Minutes per mile
Loading	--	10.1	0.0167	--
Unloading	25.3	--	0.0167	--
Driving	--	--	--	2.727
Total	25.3	10.1	0.0334	2.727

[a] Showing time spent in "productive" operations only.

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[15] On the routes studied, detailed stop-watch observations were made of the time spent driving between stops, while the corresponding distance traveled was noted from the odometer. The purpose of making these observations was to attempt to determine variations in the rate of speed which might be explained by: (1) the operation of tank trailers as contrasted to can trailers; (2) the operation of a single semi-trailer or of a semi-trailer plus a four-wheeled trailer; (3) long-haul distances (such as from the plant to the first stop, or from the last stop to the plant) as contrasted to short-haul distances (such as between ranches located in the same vicinity); and (4) the increase in gross weight to be hauled as the truck neared completion of its route.

The analysis of these observations indicates that while these factors might have been important, they were obscured by the effect of other factors such as topography, traffic, and road conditions, which were not measured and which are extremely difficult to classify objectively.

In formula terms, this may then be stated:

$$TT_t = 25.3 + 10.1\ N + 0.0334\ G + 2.727\ M,$$

where TT_t is total time for the "productive" operations performed in transferring milk from the location of its production to the processing plant, N the number of produoers shipping on that route, G the volume of milk handled in gallons, and M the round-trip mileage required for the route.

FACTORS AFFECTING TIME REQUIREMENTS ON CAN COLLECTION ROUTES

Milk is brought in from the country in cans in all sorts of types of vehicles, ranging from the farmer's own passenger car up to tractor-propelled, semi-trailer trains of the legal maximum weight and length limit.[16] The types of trucks used to haul milk in cans include the flat-rack type body, and the insulated, closed-in, van type body. The latter may have one or two doors on each side depending on the length of the van, and may have a rear door for loading. Ordinarily, at least part of the load is "double-decked," that is, one layer of cans is stacked on top of the other, usually with a removable second floor. This arrangement necessitates double handling of at least some of the cans while loading, first to get the cans into the truck, and then to place them in their proper carrying position.

The principal components of the operation of loading milk in cans are, of course, unloading the clean empty cans for the next day's pick-up, and loading the full cans. Because of the manual work involved, the total time required per stop is much more directly affected by the volume of milk handled, using the can method, than when the tanker is used. Certain other operations, however, must be performed which have no direct relation to volume.

Factors other than volume handled which affect time requirements in this type of operation include: (1) location and availability of storage space where the empty cans are to be unloaded; (2) location on the truck of the empty cans (with reference to the necessity for double-handling); (3) location and availability of full cans to be loaded; (4) presence of or absence of a loading platform which would reduce the required lifting of cans; and (5) necessity of double-handling full cans.

The net effect of the above items, while they are undoubtedly important from the standpoint of the number of foot-pounds of work required of the driver, seems to be small in relation to the single factor of volume, as expressed by the number of cans. The results of statistical analysis of the observations made of the can-loading operation indicate that approximately 84 per cent of the variance in total loading time (unloading empty cans and reloading full cans) is associated with the number of cans handled.[17]

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[16] The legal maximum limit in the State of California at the present time is a gross weight for any combination of vehicles not to exceed 76,800 pounds and an over-all length not greater than 60 feet.

[17] As evidenced by a corrected coefficient of linear correlation of 0.915 between loading time requirements and number of cans handled. No other factors which might offset loading time were tested.

[illegible below, mid portion in shadow]

[illegible] [illegible] [illegible] [

The observations of loading time indicate that on the average the total time required per stop to pick up milk in cans at the ranch can be expressed by the formula:

$$LT_c = 2.12 + 0.457C,$$

where LT_c is total time in minutes, and C the number of 10-gallon cans to be loaded.[18]

Unloading and Receiving Milk in Ten-Gallon Cans

To be considered property, the operation of unloading at the plant should be distinguished from that of receiving the milk. The unloading operation consists of unloading and then reloading cans after they have been dumped and have passed through the mechanical can-washer. This is usually performed by one man. The receiving operation, on the other hand, consists of dumping the cans, taking a sample for laboratory analysis, and recording the weight of the amount of milk received from each individual producer. Two men are normally required for this.

Unloading

The amount of time spent unloading cans is affected by conditions such as: (1) the accessibility of the conveyor belt to the loaded truck; (2) the length of the conveyor belt leading into the receiving room; (3) the freedom from mechanical breakdown of the conveyor or of the can-washer; (4) the type of truck being unloaded, whether an open flat-bed truck or a closed van which must be unloaded through a door; and, (5) whether both "Grade A" and "Grade B" milk are to be unloaded requiring that the truck must be moved from one unloading platform to the other, or else necessitating the use of two conveyor belts to the separate receiving tanks often causing a mix-up in the order of cans returning from the washer.

Time expenditures for the observed range included in the study indicate the following effect of volume (in terms of number of cans handled) on required requirements:

$$UT_c = 0.237\ C,$$

where UT_c is unloading time for cans expressed in minutes, and C the number of cans.

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[18] It should be noted here that in spite of the similarity of form of the two formulae expressing loading time requirements, they are essentially different in construction and in derivation although the final estimate derived from the use of either will be of approximately the same nature and interpretation. Because of the different nature of the tank-loading operation (i.e., which requires a certain expenditure of time preparatory to loading plus a varying amount of time to load, depending on the volume to be pumped), this formula was derived by the method of synthesis, or building up the time requirements of the component parts of the entire operation. Therefore, the magnitude of the "fixed" time per stop (10.1 minutes) is an arithmetic average of the amount of time spent at each stop which is not associated with volume, and can be represented as typical, at least of the observations noted. The slope of the line showing the rate of increase with volume (0.0167 minutes per gallon) reflects the rated capacity of those pumps used on the farms observed. On the other hand, the formula for can-loading was derived statistically by the method of least squares.

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{u}) = 0,$$

$$\rho \frac{\partial \mathbf{u}}{\partial t} + \rho (\mathbf{u} \cdot \nabla) \mathbf{u} = -\nabla p + \mu \nabla^2 \mathbf{u},$$

$$\rho \frac{\partial e}{\partial t} + \rho \mathbf{u} \cdot \nabla e = -p \nabla \cdot \mathbf{u} + \nabla \cdot (k \nabla T) + \Phi,$$

$$p = \rho R T,$$

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{u}) = 0,$$

$$\rho \frac{\partial \mathbf{u}}{\partial t} + \rho (\mathbf{u} \cdot \nabla) \mathbf{u} = -\nabla p + \mu \nabla^2 \mathbf{u},$$

$$\rho \frac{\partial e}{\partial t} + \rho \mathbf{u} \cdot \nabla e = -p \nabla \cdot \mathbf{u} + \nabla \cdot (k \nabla T) + \Phi,$$

$$p = \rho R T,$$

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{u}) = 0,$$

$$\rho \frac{\partial \mathbf{u}}{\partial t} + \rho (\mathbf{u} \cdot \nabla) \mathbf{u} = -\nabla p + \mu \nabla^2 \mathbf{u},$$

$$\rho \frac{\partial e}{\partial t} + \rho \mathbf{u} \cdot \nabla e = -p \nabla \cdot \mathbf{u} + \nabla \cdot (k \nabla T) + \Phi,$$

$$p = \rho R T,$$

Receiving Time

Since two men are usually employed in receiving milk in cans, time requirements must be doubled, or put on a "min-minutes" basis, in order to maintain comparability between operations.

The most important single item other than volume affecting the time spent in receiving is the can-washer. The rate of speed at which the operation is performed is limited by the capacity of this machine, and the majority of all interruptions due to mechanical breakdown or "jamming" are caused by this piece of equipment.

The component parts of this operation include dumping the milk into the weight tank, securing a sample, and recording the weight of the shipment received from each individual producer.

As far as volume is concerned, the results of mathematical analysis indicate that approximately 85 per cent of variation in time spent on receiving milk can be explained in terms of the number of cans handled.[19]

When expressed in equation form, and adjusted to consider the time of two men required, time expenditure in the operation of receiving can be shown as:

$$RT_c = 0.261N + 0.206\ C,$$

where RT_c is receiving time in minutes, N the number of shippers, and C the number of cans handled.

Total Time for "Productive" Operations on Milk-Collection Routes Using Can Trucks

In a manner similar to that followed for tank trucks, total time requirements for routes using cans can be summarized by the addition of the time requirements for the component operations. As no significant difference was found in terms of driving time when can or tank trailers were being used, the formula for estimating driving time will be identical with that previously described. Combining these formulae, as shown below in table 12 indicates that the computation of the total time expenditure can be accomplished satisfactorily through the formulae:

$$TT_c = 2.381\ N + .900\ C + 2.727\ M,$$

when TT_c represents total time for the "productive" operations of transferring milk in cans from its production location to the processing plant by one truck; N, the number of producers whose milk is shipped by that truck; C, the total number of cans hauled; and M, the total number of miles traveled in covering the routes.

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[19] The corrected coefficient of linear correlation is 0.921.

Table 12

Summary of Total Time Requirements for Collecting Milk in Ten Gallon Cans[a/]

Operation	Minutes per shipper	Minutes per can	Minutes per mile
Loading	2.120	0.457	--
Unloading	--	0.237	--
Receiving	0.261	0.206	--
Driving	--	--	2.727
Total	2.381	0.900	2.727

[a/] Showing time spent in "productive" operations only.

SUMMARY OF TIME-REQUIREMENTS FOR CAN AND TANK HAUL

Using the equations presented above in the estimation of time expenditure for both of the prevailing methods of collection, the effect of factors such as size of shipper, size of route, and length of route can be determined and illustrated.[20/]

Effect of the Size of Shipper

Figure 1 shows the effects of the average size of shipper, defined in terms of the quantity of milk to be picked up at one stop, upon time requirements for various sizes of loads. For purposes of confining variation to that which would reflect the effect of this factor, the distance to be traveled per route is held constant at 100 miles in the hypothetical cases shown. It is easily apparent that

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[20/] When adjustments of a route are made, such as changing the amount of milk received at one "pickup" or varying the size of the load carried by a given truck, what has been done, in effect, is to alter the "collection density" per stop or per mile of route travel. Many ways of changing density are available, involving the frequency of collection (i.e., twice a day or once a day), the use of roadside assembly and loading points, and simply taking on another shipper whose ranch is located directly on the route normally covered by the collection truck. The object, therefore, of minimizing time requirements (and consequently cost) is to maximize the density of collection. This is discussed under the headings of three of the important ways of varying collection density -- i.e., by changes in size of shipper (or volume per stop), size of load, and in mileage traveled per route. These are discussed separately to attempt to illustrate their relative importance and magnitude when isolated, but it is recognized that in actual practice, a change in route operations will normally have an effect upon at least two, if not all three, of those factors.

for small average volumes per shipper -- which would require a large number of stops to accumulate a full tanker load -- time expenditures are lower with can pick-up than with the use of a transport tank. This relation is altered as the amount to be picked up at each ranch increases. This is, of course, due primarily to the importance of the amount of "fixed" time per stop associated with the tank haul.

On ranches with small shipments, the importance of this fixed element of time expenditure -- required to make tank connections, is so great as to outweigh advantages that can be gained from the use of tanks.

Effect of Size of Load

Another factor of interest in determining total time requirements under the two methods of milk transportation is that of the amount of milk being carried per route. It is impossible to determine the net effect of this factor, due to the fact that it is obviously impossible to alter the size of load carried, without bringing about some change either in the amount of milk per shipper (size of shipper) or in the number of shippers served. The effect of increasing the size of load is illustrated in figure 2 where the load increases are brought about by the addition of more shippers (with a volume of 200 gallons per shipper) to the route. Here, again, differences in the rate of increase in time requirements are explained by the element of fixed time; primarily in terms of unloading and washing operations of the tank after it returns to the plant. Of the observations made, there was little difference discernable between the size of tank being washed and the time spent in washing.

Effect of Distance Traveled on Time Requirements

As the rate of speed at which the various types of trucks were observed to travel was the same for all practical purposes, changes in the length of route will affect both can and tank operated routes in the same manner and to the same degree. The effect of this factor can be seen in figure 3. As would be expected, driving time requirements increase at a constant rate as mileage to be covered increases.

Effect of Size of Shipper and Various Types of Loads

It is of interest to note the effect of the size of shipper when different sized loads are being collected. As can be readily seen by inspection of figure 4, the economies to be derived from the use of tank trucks are of greater magnitude both as the size of shipper and as the size of load increases. From the figure, it would appear that the point of intersection of the two curves of the 1,000-gallon load (100 cans) occurred at approximately 250 gallons per shipper; for the 3,000-gallon load, at approximately 165 gallons; and for the 5,000-gallon load, at about 155 gallons per shipper. The logical explanation of this again lies in the effect of spreading the fixed time of the tank at the plant over a larger volume.

WAGE RATES FOR DRIVERS AND PLANT EMPLOYEES

Wages paid employees of milk distributors and contract haulers operating in

Figure 1

Effect of Size of Shipper on Time Requirements

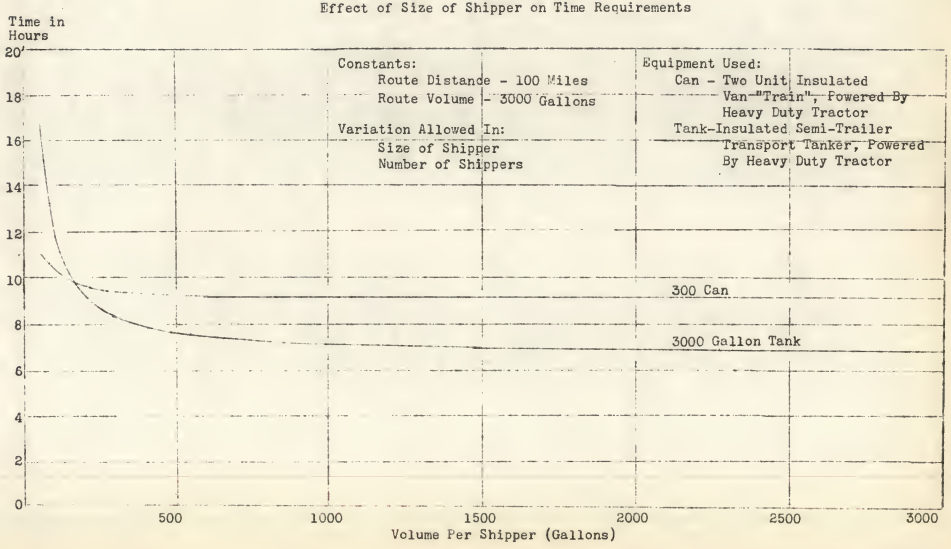
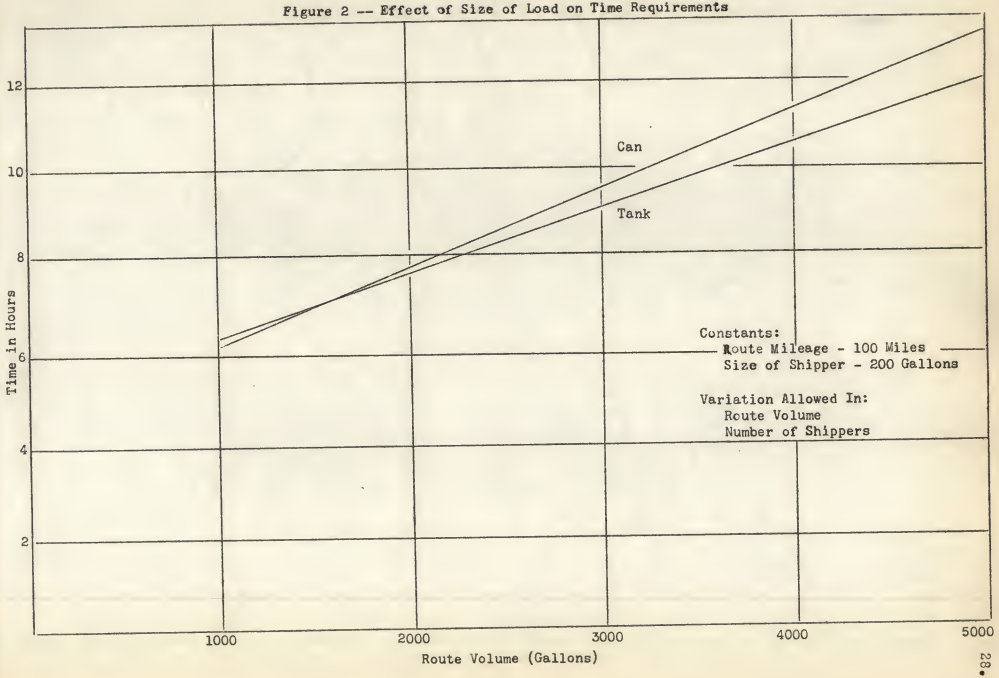


Figure 2 -- Effect of Size of Load on Time Requirements



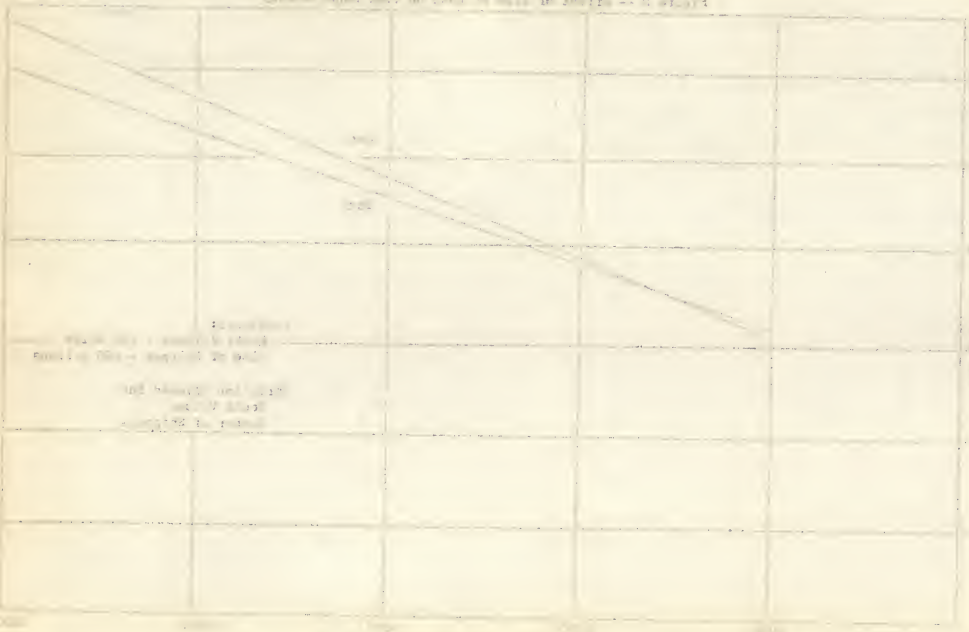
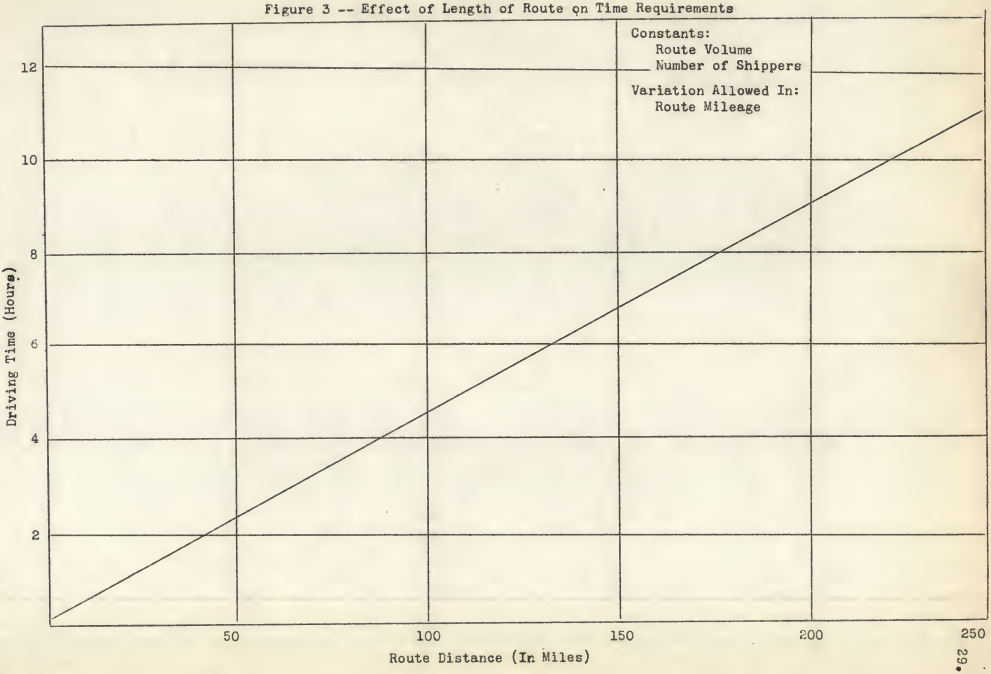
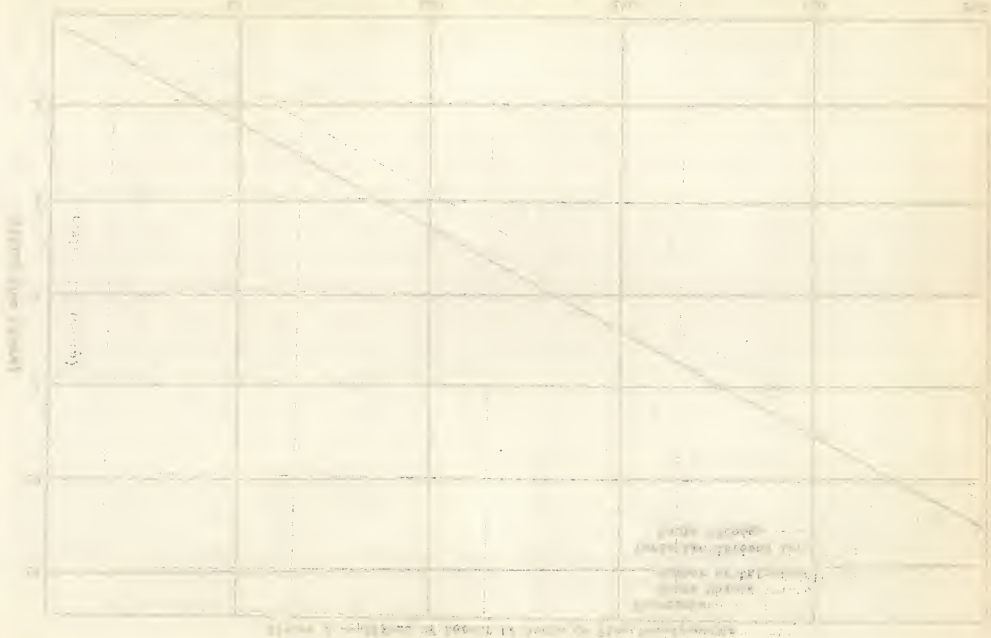


Figure 3 -- Effect of Length of Route on Time Requirements





the Bay area are determined by negotiation with the Milk Wagon Drivers Union (AFL). Agreements signed by both parties are effective for a one-year period and set forth the basic rate for each employee classification, plus provisions for hours and working conditions.

The contracts currently in force in the San Francisco and in the Alameda-Contra Costa Marketing Areas vary, particularly with regard to the calculation of overtime hours. In the Alameda area, employees are paid at the overtime rate only when the total hours worked during a month exceed the limits set forth in the contract.[21] On the other hand, employees covered under the contract in force in the San Francisco area are paid at over-time rates for any time over 8⅔ continuous hours in any calendar day.

Table 13

Summary of Hourly Wage Rates Paid Haulers and Plant Men
San Francisco and Alameda Market Areas

Classification	San Francisco		Alameda	
	Basic rate adjusted for vacation	Overtime rate	Basic rate adjusted for vacation	Overtime rate
	Dollars			
Haulers	1.787	2.54	1.765	2.51
Relief haulers	1.897	2.70	1.831	2.61
Inside men (day)	1.511	2.15	1.561	2.22
Extra inside men	1.604	2.28	1.627	2.32
Weighers and samplers	1.565	2.23	1.561	2.22
Extra weighers and samplers	1.659	2.35	1.627	2.32

In the above tabulation, basic hourly rates are shown, adjusted to include two weeks vacation with pay per year, as provided by the contract for employees with three years' service. Relief men are normally provided at the rate of one for each 2⅔ regularly employed men. Some exceptions to this exist, as in the case of haulers on routes requiring a working day of longer than 8⅔ hours. In the material which follows, however, the assumption is made that the relief man is employed at the normal rate. The composite hourly labor cost for each classification would then be:

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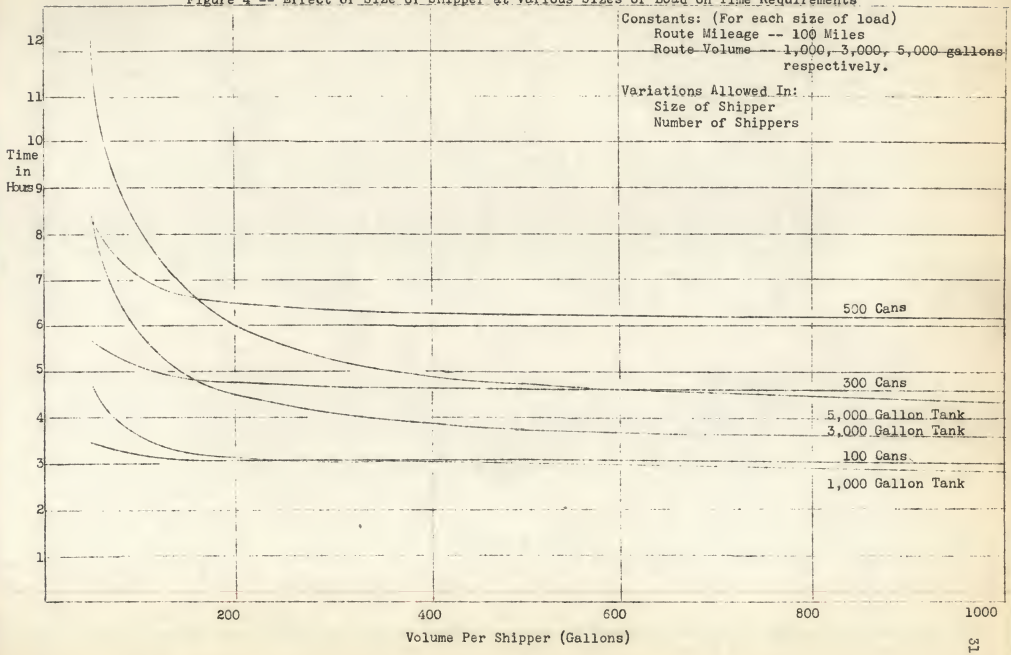
[21] These limits are: for a 31 day month, 177 hours; for a 30 day month, 171⅔ hours; and for a 28 day month, 160 hours.

[illegible]

[illegible]

[illegible]

Figure 4 -- Effect of Size of Shipper at Various Sizes of Load on Time Requirements



San Francisco		Alameda	
Hauler	$1.818	Hauler	$1.784
Inside man	1.538	Inside man or weigher and sampler	1.580
Weigher and sampler	1.592		

These composite labor costs can be applied directly to the labor requirements equations presented in the section on Labor Requirements.[22] Labor cost per thousand gallons per route, determined in the above manner, are presented in figure 5.

CONTAINER COSTS

Ten Gallon Cans

When milk is hauled from the producer's ranch to the plant in cans, it is generally estimated that three cans are required for each ten gallons daily average shipment. This estimate allows for one can at the ranch, one at the plant, and one in transit. It also considers seasonal flush periods in which increased production requires a larger number of cans. This is more or less a universal rule of thumb, covering typical conditions within the dairy industry in all of the major markets of the country. Due to the fact that production areas are located relatively close to the large consuming markets in California, requiring a shorter than average haul, it is felt that following this rule will result in excessively high can costs. In this area, full cans arriving at the plant are normally dumped, washed, and reloaded on the same truck that brought them in, and are returned to the producer's ranch at the time the next pickup is made. For purposes of arriving at a representative cost, an average of two cans for each 10 gallon pickup, determined at the peak season production, would be more satisfactory for this area.

One of the largest factors entering into the determination of can cost, and also the most difficult to forecast, is that caused by the loss or "straying" of cans. The extent to which this loss occurs depends largely upon the degree of control which the distributors hold over their shippers. Other items which enter into costs of this type are the painting of producer's numbers on

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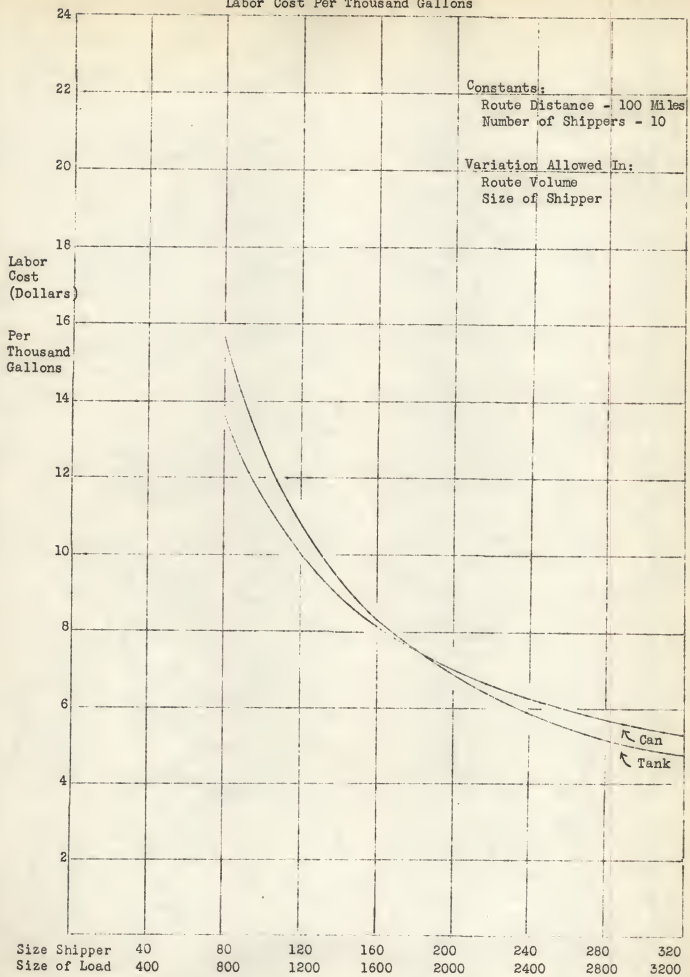
[22] These equations are: For tank operation;
Driver = 10.1N + 0.0167G + 2.727M
Inside man = 25.3 + 0.0167G
For can operation;
Driver = 2.12N + 0.0457G + 2.727M
Weigher and sampler = 0.261N + 0.0206G
Inside man = 0.0237G;
where N is number of shippers, G the volume of milk handled in gallons, and M the number of miles traveled.

Figure 5
Labor Cost Per Thousand Gallons



cans and the maintenance of the can washer and can receiving equipment.

Estimates furnished to the writer provide that the original cost of a can is approximately $6.00 at current prices. The length of life before retinning amounts to four years; the can, on the average, can be retinned twice. Each time the can is retinned, its life is increased by three years; its total life with two retinnings is ten years. The cost of retinning amounts to $2.50 per can. The life of a can lid is not as long as that of the can itself; five per cent lid replacement per year is required.

Applying the above relationships, we get the following cost rates presented here in tabular form.

Table 14

Estimates of Can Cost Per Gallon of Milk Received

	Dollars	
Original cost (at carlot rates)	6.00	
Retinning cost (twice during 10 year total life)	5.00	
Lid replacement cost (5 lids per 100 cans at 75 cents	0.38	
Total cost per can		11.38
Investment in cans per 10 gallon peak season production		22.76
Annual interest charges[a]	0.63	
Annual depreciation charges[b]	2.28	
Daily depreciation and interest charges		0.00797

[a] $I = \frac{A}{2}(r)\left(\frac{n+1}{n}\right)$. See discussion of computation of interest charges under section on Truck Operating Costs.

[b] Depreciation on straight line basis over 10 year period.

Farm Storage Tanks

At the present time, farm storage tanks are in the early stages of their development. The majority of the tanks now in operation in the Bay area milkshed are standardized, insulated, general purpose holding vats, with stainless steel lining. When the insulated holding tank is used, refrigeration of the milk is provided by a surface cooler. Variations do exist, however; some of the tanks are equipped with refrigeration facilities built in the walls of the cooler. This equipment removes the body heat from the product and insures its remaining cold in storage. In other cases, provision is made for retaining low temperatures during storage by a small surface cooler suspended in the tank. Its function is merely to maintain the desired temperature after the milk has been previously cooled by the regular surface cooler. Quite reasonably, differences in cost accompany these variations in specifications.

For the purpose of indicating comparative cost relationships between the tank operation and the can method, current cost rates will be applied to insulated holding tanks. It will be assumed that no change will be required in the cooling equipment, but, that the cooler used when cans are employed will adequately handle the milk going into the tank.

Due to the short period in which farm storage tanks have been in use, there are no experiential records from which to determine their life expectancy as a basis for calculating depreciation charges. If, however, we apply a rate of 10 per cent per year, the daily depreciation and interest charges on this type of container would be as shown below.

Table 15

Summary of Daily Depreciation and Interest Charges for Milk Storage Tanks

Size of tank (gallons)	Cost f.o.b. factory	Freight	Pump	Installation	Annual interest[a]	Daily depreciation and interest
			Dollars			
300	1,020	72	250	150	41	0.521
500	1,275	100	250	150	49	0.620
600	1,375	120	250	150	52	0.655
800	1,700	132	250	150	61	0.807
1,000	1,850	143	250	150	66	0.836

[a] Annual interest charges determined by formula $I = \frac{A}{2}(r)\left(\frac{n+1}{n}\right)$ computation of interest charges. See discussion in section on Truck Costs.

SUMMARY OF TOTAL OPERATING COSTS

In general, all of the costs discussed here can be further classified according to their direct association with either: (1) the number of shippers whose milk is being collected; (2) the number of miles to be traveled by the collection trucks; and/or (3) the total volume of milk to be handled.

Presented below in table 16 is a summary of costs discussed in foregoing sections, synthesized on the above basis. Four types of vehicle units, two for each collection method, have been arbitrarily selected as typical and representative of the more important types of equipment now in operation in this area. The footnotes below the table indicate the composition of the cost items for each classification. Here, the basic relationships between the two methods of collection become apparent. Costs associated with the number of shippers are significantly higher by tank than comparable costs for the can operation. On the other hand, those costs related directly to volume, or the number of gallons handled, are lower for the tank method. From this it can be seen that the economics of the tank operation come about where small numbers of large volume shippers are concerned. This will be discussed in more complete detail in later sections.

Table 14

Summary of Daily Operation and Lab Test Results
Ore Mill Feeder Tests

Date of Test	Feed (Tons)	Lab. Delivery	Product	Drop	Test - Duration	Normal	Daily Production (Tons)	Daily Operation (Hours)
				Option				
8/20	1,050	92	87%	13%	21		1.05%	
8/21	1,275	120	84%	120	22		1.27%	
8/22	1,375	130	88%	130	22		0.13%	
8/23	1,100	104	91%	104	20		1.10%	
8/24	1,250	118	89%	118	21		1.25%	
8/25	1,000	94	90%	94	19		1.00%	

Annual interest charges determined by formula $I = \frac{A}{N}(r + j)$ where I = annual interest charges, A = total amount of loan, N = number of years, r = rate of interest charged, j = sinking fund factor. See discussion in a chapter on Trust Funds.

CHAPTER 23 [illegible]

In general, if one more discussed here can be further classified according to their direct connection with subject: (1) the number of workers directly is being collected; (2) the number of miles to be traveled by the collection trucks; and/or (3) the total volume of milk to be hauled.

Presented below is data in a survey of cards dispersed in [illegible] sampling, distributed on the above basis. Four types of visits, refer, the most collection method, were then randomly selected from the [illegible] of the two days of the more important types of customers are in operation in this area. [illegible] records below are daily indices the complexities of the most items for each classification. Here, this basis relationships between the two methods of collection become apparent. Cards arranged with the number of shipments are likewise higher in less time consuming cards for the most operation. On the [illegible], those cards marked alphabetically or the number of milking hours, [illegible] cards for the tank method. From this it can be seen that the [illegible] that operation come about very small numbers of large volume milk as was assumed. This will be discussed in more complete detail in later sections.

Table 16

Summary of Milk Collection Costs (total costs)

	Cost associated with each shipper[a]	Cost associated with each mile[b]	Cost associated with each gallon of indicated capacity[c]
	Dollars		
Light duty semi-trailer; average capacity 135 cans	0.0732	0.1939	0.0057
Heavy duty semi-plus trailer; average capacity 350 cans	0.0732	0.2489	0.0055
Heavy duty semi-tank; average capacity 3,500 gallons	0.3002	0.2433	0.0050[d]
Heavy duty semi-plus trailer tanks; average capacity 4,500 gallons	0.3002	0.2489	0.0053[d]

[a] Includes labor cost of additional time of driver and receiver for each additional shipper. (Time of driver $\lfloor 10.1N \rfloor$ times driver's wages, etc.)

[b] Includes variable truck costs and driver's time spent driving.

[c] Includes fixed truck costs, container costs, driver's time spent loading and unloading, and receiving costs.

[d] Container costs determined at 300 gallon size shipper.

Comparison of Cost Relationship

In the previous sections, cost rates for truck operation, labor requirements, and containers have been indicated. These now can be applied to route conditions to indicate the relationships between costs of hauling milk by the can method or by tank. Attention has been purposely directed to the net effect of differences in costs which accompany changes in: (1) the factor of volume, which considers total size of load carried, and the number and the size of shippers; and (2) distance traveled. Due to the importance of the effect of the size of shipper, considerable attention is drawn to this relationship.

Average Collection and Transportation Costs

It is possible to apply the cost rates developed in this report only when specific values of the variable route factors (that is, number and size of shippers

and route distance) are known. To develop and illustrate the relative levels of per gallon costs as collection volumes increase, arbitrary values of these factors have been selected. The resulting cost curves are shown in figure 6. The following circumstances were assumed to apply in regard to route conditions.

(1) The size of shipper being served is 300 gallons. Increases in volume, therefore, occur through increasing the number of shippers.

(2) All collections are made in a single production area located 30 miles from the processing plant. Each additional vehicle-unit required will add 60 miles to distance traveled.

(3) The production density and producer locations are uniform throughout the production area. Each additional shipper will increase total distance traveled by two miles.

The per gallon costs, as shown in the figure, decrease rapidly with the increased utilization of capacity. When the capacity of the individual unit is reached, however, it then becomes necessary to add another unit. Due to the fact that the additional unit must also make the trip from the plant to the production area, costs are increased to a greater extent than volume, and per gallon costs rise. As more and more individual units are added, the percentage of mileage increase, caused by one truck making the round-trip to the country, becomes less and less important. Therefore the height of the peaks of the saw-toothed curve becomes less with increased volume, and the slope of the curve between peaks diminishes.

In considering the relationships of these average costs, it can be seen that for any volume larger than the capacity of a single small truck the use of the larger van-can truck or the single semi-trailer tanker would result in lower costs.[23]

Average costs for the largest unit, the semi-trailer plus trailer-tank train, with a capacity of 4,500 gallons, while showing the lowest average costs as it approaches full capacity, are only lower than the single-unit tank or the large van-tank truck within the range in which it is operating at a higher percentage of capacity than is the somewhat smaller unit.

EFFECT OF SIZE OF SHIPPER ON TOTAL COST

By applying the cost rates to strict and arbitrary route conditions, the

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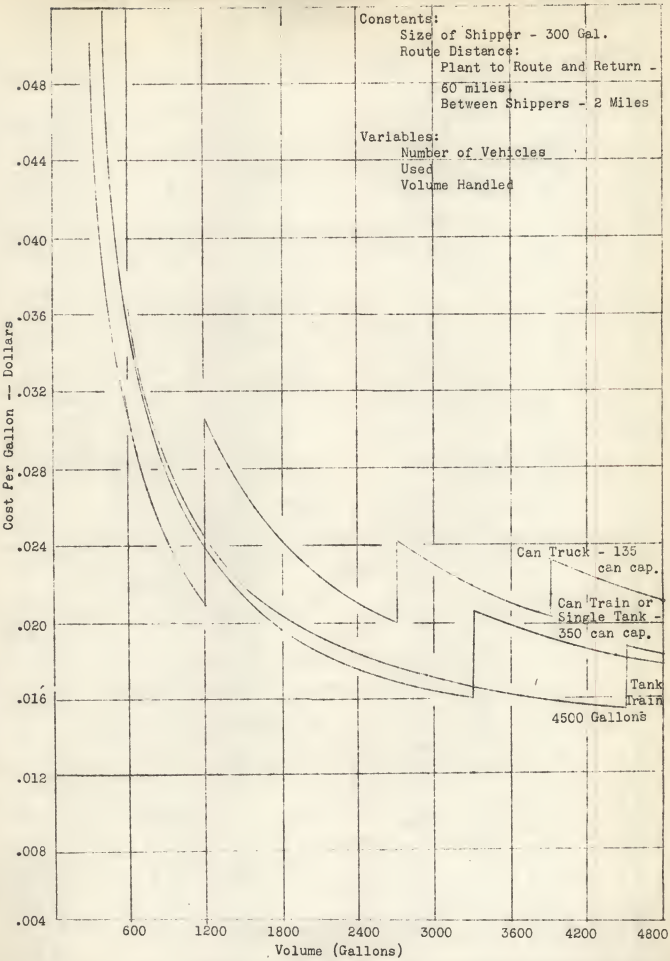
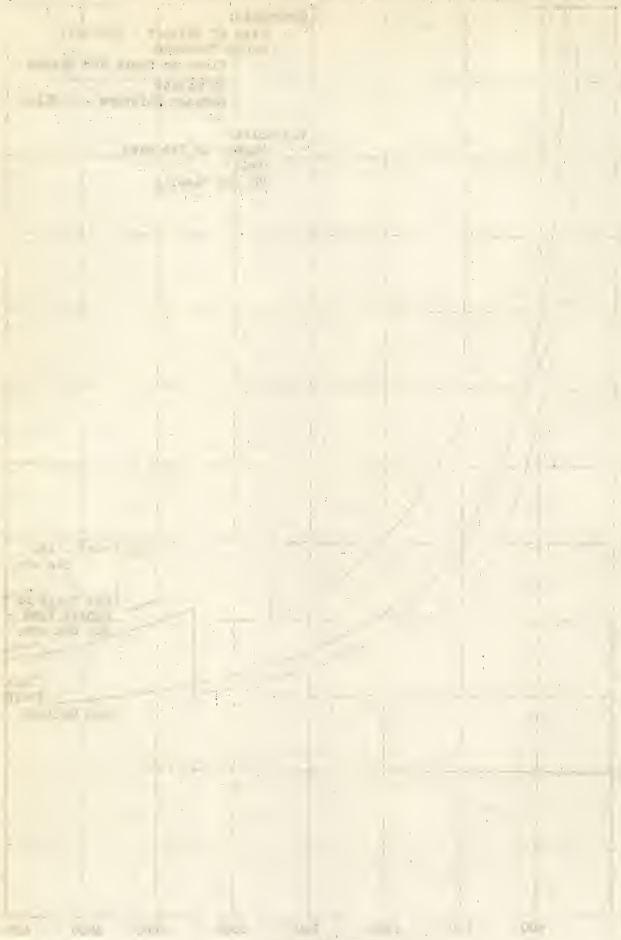
[23] This would not be true, however, in the case where relatively short distances are required to travel from plants to production area and return, or in any case where the increase of total mileage through the addition of units was insignificant. In this example, for instance, if the percentage of travel between plant and production area and return had been less than 18 per cent of total mileage, costs for the smaller truck would have been the lowest throughout the range of volume. The conditions as selected and described for use above, in which a large percentage (approximately 60 per cent) of total mileage is spent on open highways, is felt to be more realistic.

Figure 6 Comparison of Costs Per Gallon - Collection and Transportation





total cost of truck operations, "productive" labor, and container charges can be estimated for milk collection under either method, using any appropriate combination of vehicle unit or tank sizes indicated. In addition, the relative costs for any combination can be seen. In figure 7 are shown the total costs of milk collection by can method and by tank, which indicate differences associated with the size of the shipper handled.[24] In this illustration, comparable operating conditions have been assumed. That is to say, in both methods the milk is collected once a day, each route carries a total of 3,000 gallons (300 cans), and travels a total route distance of 100 miles. It has been further assumed that both collection vehicles will be powered by similar heavy-duty tractors. The can method requires two insulated vans, a semi-trailer and a trailer. The tank, on the other hand, is a single unit semi-trailer. It can be easily seen that the size of shipper has relatively little effect upon milk collection costs by can for shippers larger than 200 gallons (or 20 cans) per day. On the other hand, total costs for the tank method fall off rapidly during the entire range of sizes of shippers indicated here. This is due to two main causes: (1) the importance of the fixed labor cost involved in making connections, agitating the milk, taking samples required for each stop at which milk is collected; and, (2) the high container costs per gallon associated with small quantities of milk. In figure 7, two cost functions are shown for the can method. The solid line excludes the cost of equipment at the plant, such as can washers, receiving and weighing tanks, scales and conveyor. With the broken line, an estimate of these costs, reduced to a daily basis, is included. The inclusion of these costs naturally increases the cost level of the can method, and also affects the point at which the two types of curves intersect; which might be termed the "break-even" point. Consideration should be given to both of these cost functions, since, in many cases, plants considering a change in method of collection have not only already incurred most of the receiving equipment costs, but would also find that they continued to require the use of this receiving equipment, either as a "standby" in the eventuality of mechanical breakdown of some sort, to handle shipments from smaller producers not converted to the tank method, or to facilitate the handling of "house cans." A similar type of cost of the can method, at least when once-a-day pickup is made, that is not considered here, is that of the "cold box" facilities at the ranch to hold the required low temperature until the milk is collected. The cost of this equipment is usually borne by the producer and forms a significant part of the costs of the can method. However, on farms when the investment has already been made, only a small fraction of the original cost or value can usually be realized in salvage. It should be borne in mind, that when the relative costs are considered for a "shift-over" from can to tank method, "sunk" costs of the type mentioned above are unimportant. In this case, it would be the costs of the can method less those costs already incurred, which should be measured against the total costs of the tank method.

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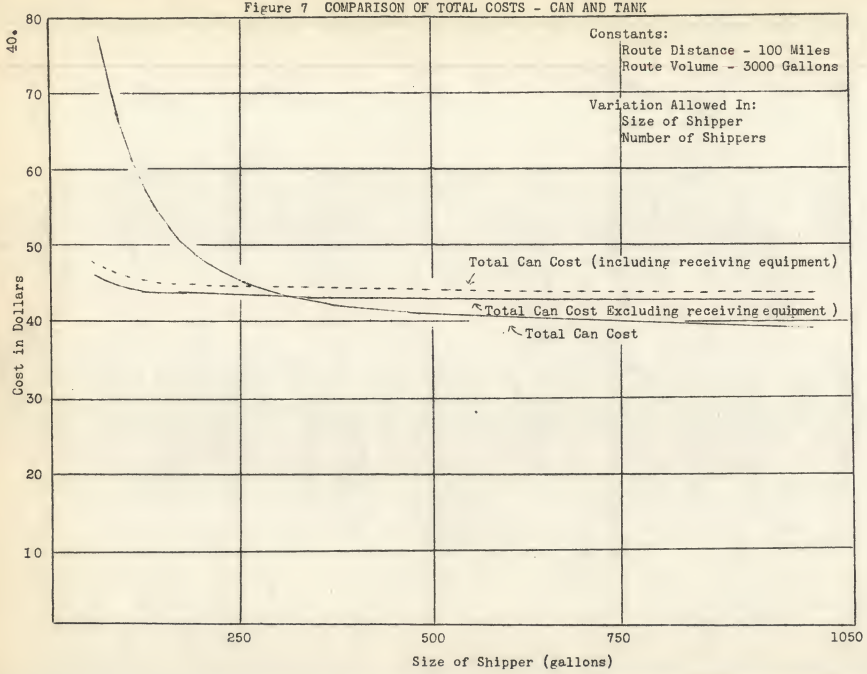
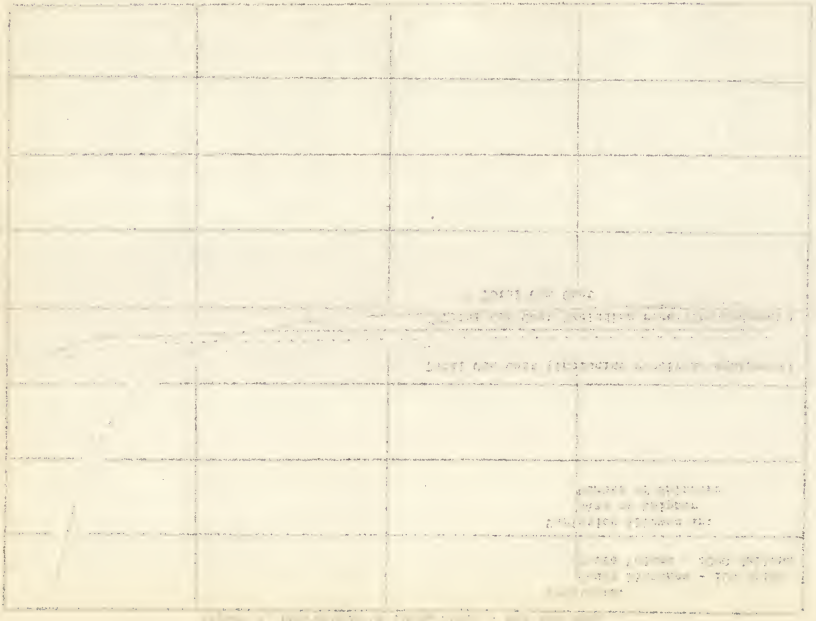
[24] It should be noted that while the curves shown in figure 7 indicate total costs, they are not to be confused with the "total cost curves" familiar to the economic theorist. The latter, since they indicate aggregate costs which accompany an increasing volume, must of necessity be positively inclined throughout their length. The curves presented in this figure, however, indicate total costs for a given volume (3,000 gallons per load) when one of the factors contributing to cost (the number of shippers whose output must be collected in order to acquire that volume) diminishes in value through the corollary effect of increase in the size of the individual shipper served.

Figure 7 COMPARISON OF TOTAL COSTS - CAN AND TANK





Effect of Size of Shipper on Composition of Collection Cost

From inspection of figure 7 the magnitude and the relation of total collection costs for the two methods under the specified operating assumptions can be seen. It is not feasible, in this type of chart, to indicate the changes in the component elements of total cost which have brought about this relationship, and for this reason, figure 8 is presented. Here are shown, in the form of bar diagrams, the respective proportions of labor cost, truck cost, and container cost that make up total costs under the same conditions specified in figure 7. These are: (1) that a total route distance of 100 miles is covered; and, (2) that a total route volume of 3,000 gallons is collected. Variations in cost, therefore, are associated directly with the size of shipper served, and conversely with the related effect of number of shippers required to make up the specified route volume. The equipment used for this illustration, as in the case of figure 7, consisted of a two unit insulated van "train," powered by a heavy-duty tractor for the can method, and a semi-trailer transport tank, also powered by a heavy-duty tractor, for the tank method.

From this illustration of operating costs under the specified conditions, two important factors relating to the effect of size of shipper can be seen. In the first place, where the can method is used, size of shipper, per se, has no effect upon the absolute magnitude of either truck costs or container (can) cost, since the same mileage and load weight will be required, and the same number of cans (for a 3,000 gallon load) will be used irrespective of the number of shippers served. Any effect caused by size of shipper, therefore, must result from the relation of that factor to labor cost, and further, through only that portion of labor cost which is "fixed," or unrelated to volume. As the amount of this "fixed" time is small in relation to total labor expenditure, the effect of increasing the size of shipper (decreasing the number served) is relatively unimportant when the can method is used. On the other hand, when tanks are employed, increases in the size of shipper decrease both labor cost and container (tank) cost, while only the total of truck costs remains constant. The explanation of this is that the importance of "fixed" time (unrelated to volume) per shipper is large in the tank method relative to cans and therefore has a greater effect in decreasing labor cost as size of shipper increases (number of shippers decreasing). Secondly, container costs are affected in two ways. With small shippers (less than 300 gallons) tank capacity is insufficiently utilized, and increases in size of shipper up to 300 gallons (the smallest size farm storage tank currently available) does not increase container cost per shipper -- even though number of shippers is decreased, and, when tanks larger than 300 gallons are required, container costs increase less than proportionately to increases in volume causing a consequent decrease per gallon in container costs.

Another type of comparison between the two methods can be made by considering the alternatives of once-a-day tank pickup, using a large tank truck, with a twice-a-day can pickup in which a light-duty open-body trailer is used. Here, in addition to changing methods, the collection density per mile of travel is doubled by the reduction in number of pickups, and the volume per shipper is doubled. A comparison of the cost relationships for these conditions is shown in figure 9. In this example a total of 3,000 gallons of milk is picked up at ten ranches on a one hundred mile route. When cans are used, the light duty truck is required to make two complete trips, or a total of 200 miles, and makes twenty pickups, two from each ranch. On the other hand, the heavy duty tanker makes but one pickup each day at which time the product of two milkings is collected. The importance of the effect of the once-a-day type of pickup can be

Figure 8 - EFFECT OF SIZE OF SHIPPER ON MAGNITUDE AND COMPOSITION OF COLLECTION COSTS

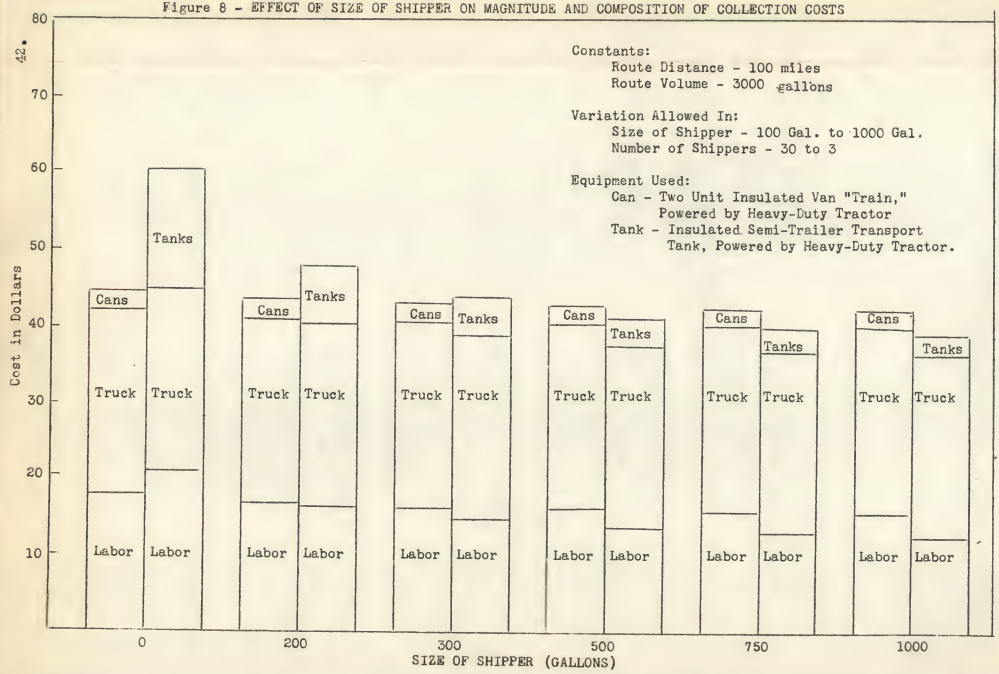
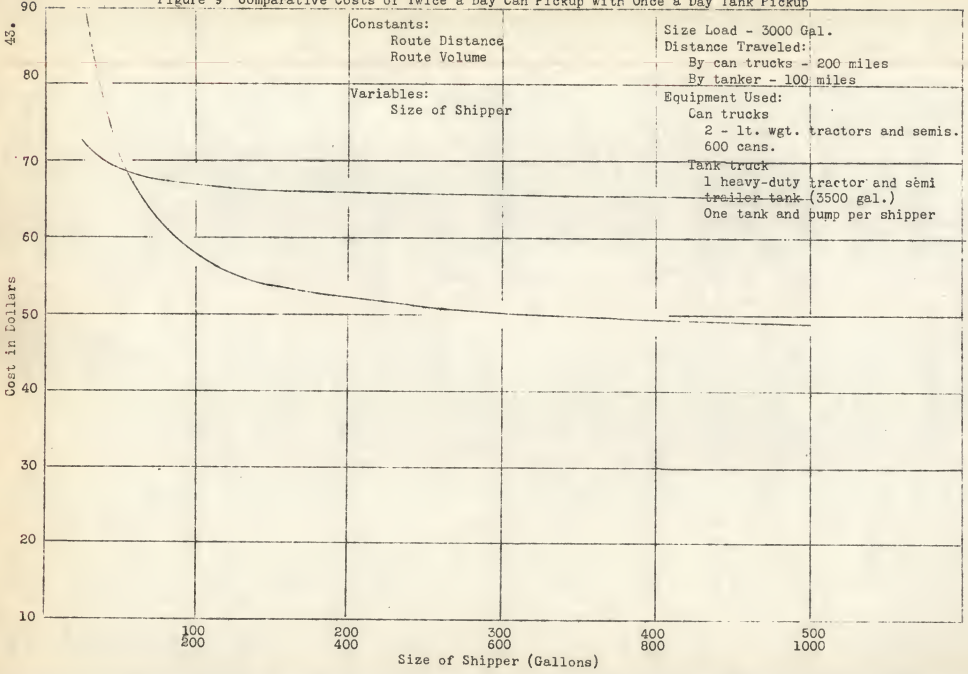


Figure 9 Comparative Costs of Twice a Day Can Pickup with Once a Day Tank Pickup



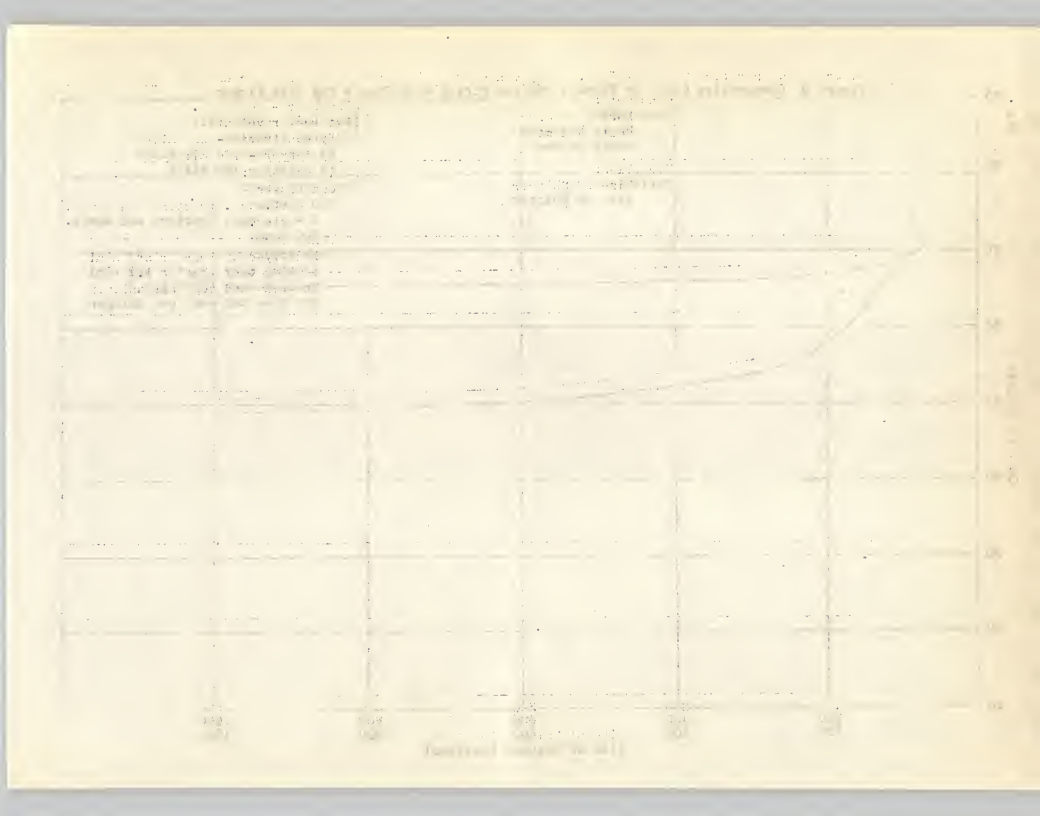
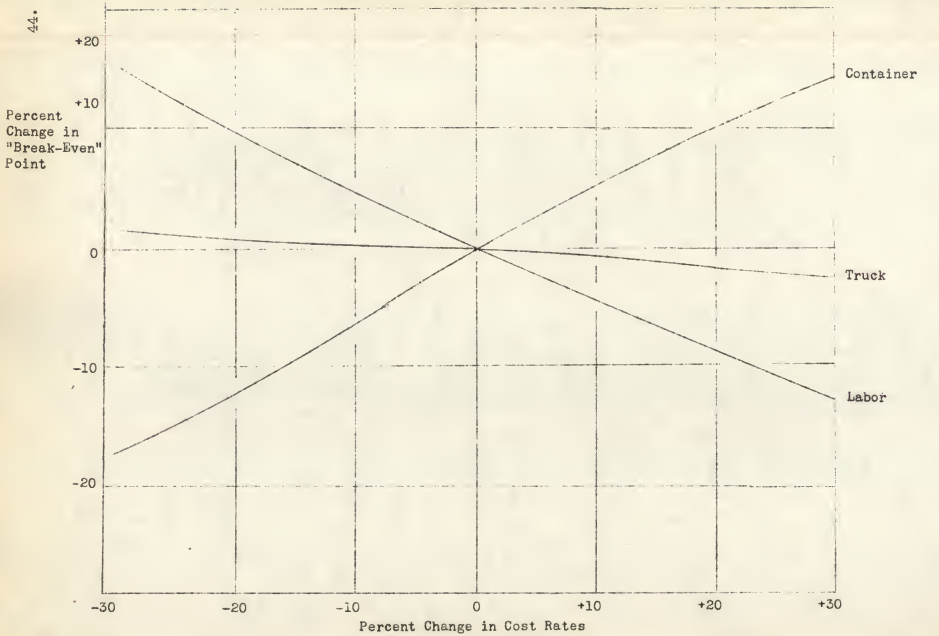
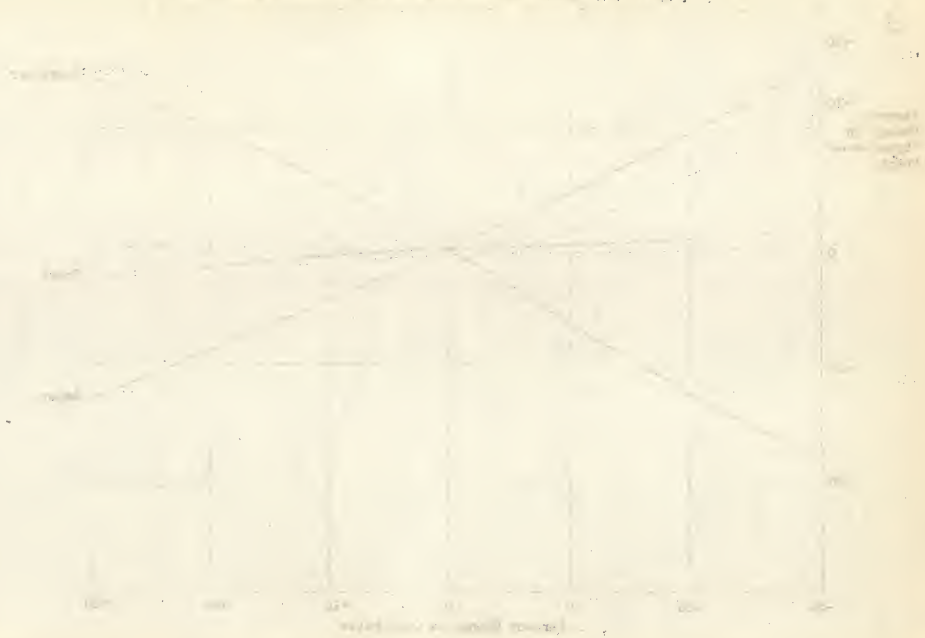


Figure 10
Effect of Changing Cost Rates on The "Break-Even" Point





seen by comparison of the intersection of the two curves, or the "break-even point" in this figure with that of figure 7.

For the sake of simplicity in developing these hypothetical examples to illustrate the effect upon costs of some of the more important factors involved in milk collection and transportation, some highly unrealistic conditions have been assumed. For example, when considering the effect of the size of shipper -- that all shippers served on a particular route are of identical size. Under actual conditions, a given production area which might be considered for the purpose of making up a route, would more likely present large variation in amounts of milk produced between shippers.

It can be shown that the effects of this assumption of uniform size of shippers are not serious. Truck and labor costs -- for any given mileage, volume, and number of shippers -- will remain unchanged with variations in the individual quantity of output of the shippers which constitute that volume. Container costs, on the other hand, will be affected in two ways: (1) to the extent that farm storage tank capacity is not utilized sufficiently, (the smallest size currently available is approximately 300 gallons); and, (2) to the extent that cost for a single tank increases in a decreasing proportion to tank capacity. These effects are minimized by the fact that container cost constitutes a relatively small portion of the total cost. For example, in the instance of 300 gallon shippers, container costs for a 3,000 gallon route, volume would be increased by 12 per cent where, instead of serving ten 300 gallon shippers, eight 125 gallon and two 1,000 gallon shippers make up the total volume. This, in turn, increases total cost by only 1.5 per cent.

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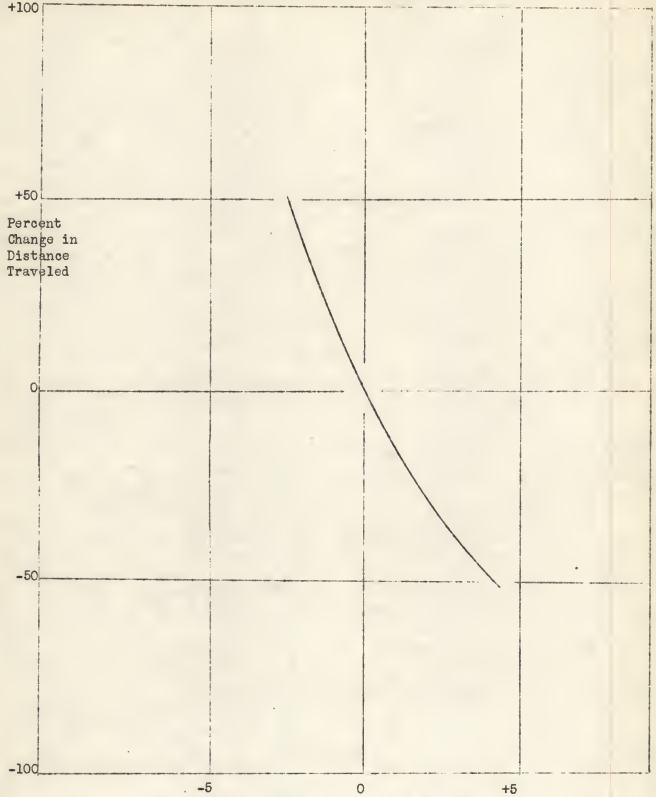
Cost rates for the items used in milk collection are subject to wide variations. In recent months, for example, several changes in gasoline prices have come about. Fluctuation in equipment prices can be expected in the future with differences in demand conditions and in the availability of raw materials. Figure 10 shows the direction and the approximate magnitude of various percentage changes in truck, labor, and container costs in terms of the location of the "break-even" point. From this it can be seen that an increase in either labor or truck costs would make it economical to shift to the tank method at a relatively lower volume per shipper, while an increase in container costs would increase the size of shipper at which the "break-even" point occurred.

Another factor of importance, concerning the relationships of the two types of cost functions, is that of the distance traveled in making the collections. As indicated in figure 11, the tank method is relatively more economical than the can method, as the total distance to be traveled in making route collections increases.

Figure 11

Effect of Distance Traveled on "Break-Even" Point